



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>









THE
ELECTROTHERMOLOGY OF
CHEMISTRY

Hall
PLN
637

Printed by R. & R. Clark

FOR

EDMONSTON & DOUGLAS, EDINBURGH.

LONDON . . . HAMILTON, ADAMS, AND CO.

CAMBRIDGE . . . MACMILLAN AND CO.

GLASGOW . . . JAMES MACLEHOSF.

NEW THEORY OF GALVANISM

THE

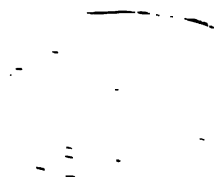
ELECTROTHERMOLOGY OF
CHEMISTRY

ELECTRICITY AND HEAT PHASES OF THE
SAME PRINCIPLE

BY
THOMAS WRIGHT HALL
M.D., L.R.C.S.E.

EDINBURGH
EDMONSTON & DOUGLAS

1872 W



MY VAX
SUBS
VAX

PREFACE.

HEAT, Electricity, Chemistry, are things of ever-growing interest, and therefore the choice of these as subjects of speculation and study, needs little apology. But it must be confessed that our handling of these fascinating themes may not be so fortunate, and may provoke speedy scientific anathema ; all the more that, in this perhaps presumptuous effort, Heat is viewed in entirely novel aspects. Heat is considered no longer exclusively a thing of thermometers and pyrometers, but as a great power in chemistry.

Heat is held the fundamental cause of most of the beautiful, complex, and enigmatical phenomena of chemistry.

Heat is considered to be as closely kin to Electricity as is infancy to manhood, and thus to be all-worthy of scientific apotheosis.

To one viewing Heat in such novel aspects, it is clear that new ideas must have occurred, and, consequently, new words, to express these ideas, became indispensable ; and I am indebted to Professor P. G.

Tait of Edinburgh, for his valuable suggestion of the word "thermic," to express certain conditions of heat supposed by me to exist in chemicals. In addition to "thermic," I have been forced to use, throughout this essay, several other new terms. I am aware that these new words may sound uncouth, but their absolute necessity, for the intelligible explanation of my views, will, I hope, excuse their employment, and in a measure disarm stringent criticism. I may farther state, as an apology for having published at all these ideas about heat, that no other better way of testing whether these ideas were true or false could be found.

CONTENTS.

PART I.

THERMOCHEMICS.

CHAPTER I.

Importance of Heat in Chemistry—Chemical Heat, that is, Heat of Condition—Specific Heat, and Weight or Grain Heat of chemicals—What meant by Chemical Heat of Condition, and Chemical Specific Heat, and Chemical Weight Heat—Heat tests or axioms assumed—The chemically thermic Metals—The thermally irregular Metals—Hints of the effects of chemical Heat on chemical behaviour Pages 1-10

CHAPTER II.

Conditional Heat changes or discharges during chemical binary combination—Heat discharged from both Combiners—Heat discharged into both Combiners—Heat discharged from one Combiner to the other—These conditional Heat discharges, like Electric discharges, lead to a Heat Equilibrium—The reverse Heat changes during binary decompositions—Heat of Metallicity 11-19

CHAPTER III.

Heat a great cause of form change in Nature—It turns visible Ice into invisible Steam; if our axioms be granted Heat is the cause of the Allotropies of Chemicals—Heat the cause of form change in Chemistry—Chemical compounds a mixture of Allotropies or Glowshapes of their ingredients 20-26

CHAPTER IV.

Effects of accumulation of chemical Heat or the reverse in Metals—Thermic Metals repel Heat and attract Cold, and have a tendency to form change—Chemically athermic Metals attract Heat, and have but little tendency to form change, for form change is indeed a Heat effect, and the more you heat a Metal, or the hotter it is naturally, the more readily it will transform chemically—Thermic chemicals attract the athermic chemicals, and *vice versa*, hence chemicals possessing strong chemical affinities must be in opposite states of chemical heat—This attempted to be proved in Metals, and metal-attracting Metalloids in Acids and Bases Pages 27-44

CHAPTER V.

The three great steps of chemical combinations—Attraction, Heat Changes, and Heat Equilibrium, illustrated by the thermics of Carbon, Platinum, Mercury, Hydrogen, Oxygen, Nitrogen, Chlorine, Phosphorus, 45-68

CHAPTER VI.

Of cooling, or refrigeration, or athermizing in Chemistry, as seen in Platinum and its congeners 69-72

CHAPTER VII.

Effects of Heat Equilibrium in Chemistry, that is, of the equal or like heat that ingredients of compounds must have while in combination—Equality or similarity in their heats produce Repulsion of the ingredients of chemical compounds—The Polarity of Repulsion of the ingredients of compounds—The reason why those ingredients, though they repel each other, yet do not separate—Illustrations of the equality and inequality of Heat producing Repulsion and Attraction, like Electric Repulsion and Attraction 73-81

CHAPTER VIII.

Of true Chemical Affinities and Aptitudes—Chemical Shapecraft—Of Chemical activity—Chemical inactivity illustrated—Of 82-89

CHAPTER IX.

The thermics of the combinations of Acids and Bases ; such combinations, attended by heat discharges, are in fact combustions similar to oxy-metallic combustions, but the heat not so violent or evident—The existence in Chemistry of the heat of acidity, like that of metallicity, lost when the acid salifies ; gained when acids regain their acid glowshapes—that is, the transformations of Acids into and from Salts are attended by loss and gain of heat—The effects of this law on the behaviour of acids decomposing salt solutions . . . Pages 90-101

CHAPTER X.

On decomposition of water by Metals—Heat required then to evolve Hydrogen, good fuel therefore needed—Potassium, etc., decomposes water—Because Potassium is thermic, is good fuel—What is good fuel ?—Zinc not being good enough fuel requires farther the combustion of an acid to decompose water—Hydrogen and Oxygen the best fuel known . . . 102-104

PART II.

GALVANIC BATTERY.

ELECTROTHERMOLOGY OF CHEMISTRY.

CHAPTER I.

Zinc burns and Hydrogen boils in the Galvanic Battery ; the heat of the Zinc combustion is discharged into the boiling Hydrogen—Effect of the presence and contact of *chemically* athermic Platinum on this Zinc heat discharge—The Zinc heat is attracted by the athermic Platinum, and passes along the wire uniting the two metals, and can be seen on the wire 105-113

CHAPTER II.

Many-celled Batteries, the course of Heat discharges in them—Compression in such Batteries of the Heat—The principle of Galvanism must be held Morphigenic Heat—that is, not Electricity proper, but a phase of it - Pages 114-119

CHAPTER III.

The old Galvanic Theory compared with the new advanced in this paper—Errors of the old views attempted to be corrected in the new—Direction of the Galvanic current—Ocular proof that it is from the Zinc to the Platinum—*No* current in the fluid of the cells 120-129

CHAPTER IV.

Transfer and attraction of chemicals in the fluid of the cells—Polar Phenomena, their nature and explanation—Identity of common and Chemo-Electricities—The New Theory of Galvanism 130-145

CHAPTER V.

Electrolysis—An Electrolyte but another cell that has been added to the Battery—Polarisation of the Electrodes—The fluid of the Electrolyte corresponds with that of the true Galvanic cell—New names of the Electrodes—Of the Zincoid Electrode—of the Platinoid Electrode—The reason that Galvanic decompositions are limited—Proofs of the identity of Electrolytes with the common Galvanic cell—Electrolysis of water, or rather weak Sulphuric Acid—Polarity and transfer of Electrolysis—Passage of Acids through blue colour, etc., etc., without reddening or affecting them 146-159

CHAPTER VI.

Recapitulation—Are our Three Axioms inadmissible?—Organic Chemistry—Some application of the Theory—Conclusion 160-173

PART I.

THERMOCHEMICS.

CHAPTER I.

IF powdered antimony be thrown into chlorine gas, the chemical action between these two substances is so strong that the antimony at once takes fire and burns brightly into the terchloride of antimony. But if, according to Schrötter (*Chemie*, vol. i. p. 129), the antimony and the chlorine be both cooled down to minus 106° by a bath of solid carbonic acid and ether, then the chlorine and antimony, thus cooled, refuse to combine chemically, and remain in intimate contact as passively as if they were sand and common air. Again, if antimony be exposed to dry or moist air for any length of time, antimony remains unaffected chemically by the air, but if the self-same antimony be *heated* in the self-same air, the heated antimony at once combines with the air, takes fire, oxidises, burns into the teroxide of antimony.

These simplest of chemical experiments are not

the less suggestive, and prove the great fact that heat exerts the following most remarkable influences on chemical action :—

Heat, that is change of temperature, may nullify or prevent chemical action, though that action be of the most violent nature.

Heat, or change of temperature, may intensify chemical action, though of the weakest kind.

That is, simple changes of temperature alone ; certain determinate states of heat may destroy or may create, *pro tempore*, chemical action. Now this is surely very suggestive, for if the above simple and artificial states of heat in bodies prove so potent in chemistry, it at once occurs to the mind to ask, What effect shall the much more perfect natural states of heat, that is heat properties of chemicals, have on their chemical behaviours ? and in order to answer that question we proceed to study what I shall venture to call “Thermochemicals,” that is the consideration of heat as a Specialty in chemistry.

The most prominent heat states or heat properties of chemicals are their conditional heat, their specific heat, their weight heat, and their conduction of heat.

If we examine the condition of chemicals, say, for convenience and perspicuity, those of the metals and the metalloid oxygen, we find those conditions very varied and very different one from another. One

metal, hydrogen, exists as an unliquefied gas, that is a gas far from liquidity, far from a *form change*.

Another metal, mercury, is a liquid.

Another metal, potassium, is a solid, but a solid that is near liquidity—that is, that is easily fused, that is near to a form change.

Another metal, zinc, is a solid, but a solid not so near liquidity, not so fusible, not so near a form change as is potassium.

Lastly, another metal, platinum, is a solid, and a solid very far from liquidity, very difficult of fusion, very far from a form change.

Now it seems to me impossible to doubt that heat must have a direct and necessary influence in causing these wide differences in the physical condition or forms of the above-mentioned metals. For let us take the two metals hydrogen and platinum, and contrast them thermally.

Hydrogen is an unliquefied gas.

Platinum is a well-nigh infusible solid.

Now it seems to me utterly impossible to conceive or suppose that gaseous hydrogen and infusible platinum can have equal heatfulness, can have the self-same amount of heat in their ultimate molecules, for hydrogen is, as it were, many times more thermic or heatful than the hottest of steams, and platinum many times more athermic or heatless than the coldest of ice. Hydrogen being an exceedingly rarefied gas,

zinc, potassium, and platinum, there will exist much more concentrated heat, latent in potassium and zinc than in platinum.

We will therefore assume it as an axiom that the less the atomic weight a metal has, the greater its heat capacities; the more thermic or heatful atomically, as I shall term it, the metal generally is.

So that of all the fore-mentioned metals hydrogen is atomically most thermic, because hydrogen's atomic weight is 1, the smallest atomic weight among chemicals. Next to hydrogen in the said metals comes potassium, for potassium's capacity for heat is as 39; after potassium comes zinc, whose capacity for heat is as 65; then platinum, which is as 197; then last of all is mercury, which is as 200, and which is thus the coldest atomed metal in our short list.

So that the capacity for heat of simple bodies, or, what is nearly the same thing, their atomic weights, afford also a most valuable indication of the atomical heat states of simple metals.

But the third great heat property of metals is what I shall term their weight heat, their mass heat, their grain heat; for just as heat influences a metal's expansion, so heat influences a metal's specific gravity; and just as a metal's expansion has been taken and used as a heat indicator, I propose that a metal's specific gravity be used as a special heat index, as a chemical thermometer; and as the effect of heat is to

make metals lighter, I will assume it as axiomatic that the lighter a metal is the hotter grained it is.

Thus, of the already-mentioned metals, hydrogen is the hottest grained, inasmuch as hydrogen is the lightest of them. Next to hydrogen comes potassium, for potassium is certainly heavier than hydrogen, and lighter than all the others of the said metals. After potassium comes zinc, then mercury, and last platinum.

Our fourth great heat property of metals is their conduction of heat, and this must be held also of extreme importance, for it is clear that, whatever be the influence and effects of heat in chemical action, conduction of heat in a chemical must facilitate those heat actions, as non-conduction of heat must impede them.

So that there are, at *least*, three ways in which a metal can be chemically thermic or athermic, heatful or heatless—by *condition*, by *specific heat*, and by *weight*. Some metals, as hydrogen and potassium, are heatful by all these three tests; and these metals are therefore types, or our beau ideals, of chemically thermic metals,—are very thermic, calorous, heatful indeed, very positive or plus as to heat, for they are hot conditioned, hot grained, and hot atomed. Some metals, on the contrary, such as platinum, are athermic by all these three tests, and are therefore our beau ideals of chemically athermic or heatless, or non-calorous metals, and are very ather-

mic indeed, very negative or minus as to heat, for they are cold conditioned, cold grained, and cold atomed. Mercury is, however, very thermic conditionally, but so athermic atomed and grained that mercury ranks more as an athermic or heat negative metal than as a thermic one, for mercury is very heavy and has very low specific heat. The heat properties of mercury counterbalance each other, not an unusual occurrence in chemistry.

In the simple experiments with which we began this paper, the changes of temperature to which antimony and chlorine were subjected by Schrötter were wholly artificial. But if we apply our axioms and rules just enumerated, we find that nature has made for us analogous experiments, for nature has cooled down platinum in a bath many times colder than that of the solid carbonic acid and ether, and heated up hydrogen in furnaces far hotter than any made with hands, and with quite analogous chemical results to those produced by the cooling or heating of puny art. For chemically thermic potassium and thermic hydrogen have most violent chemical activity, and the very chemically athermic platinum is one of the most inactive of chemicals ; while irregularly thermic and athermic mercury presents chemical actions corresponding to such unsymmetric heat properties.

We have thus found or assumed that there exists in hydrogen, mercury, potassium, zinc, and

platinum, and consequently in the rest of the metals, a conditional, atomic, and grain heat, which in a way can be tested or discovered by the states of gaseity, fluidity, solidity, fusibility, weight, and atomic weights of these metals. Thus hydrogen, I repeat, must be held chemically the most thermic in every respect, the most heat positive, of the said metals, because hydrogen is an unliquefied gas, is light, and light atomic weighted.

Platinum is to be considered the most athermic chemically in every respect, the most heat negative of the said metals, because platinum is well-nigh infusible, is heavy, and is heavy atomic weighted.

Potassium and zinc are to be held thermic or heatful compared with platinum, and athermic or heatless when contrasted with hydrogen; for potassium and zinc are more fusible and lighter, and lighter atomic weighted than platinum, but less fusible, less light, less lightly atomic weighted than is hydrogen.

So that henceforth it will be taken as conceded in this disquisition that there exists in all metals a special, inherent, conditional, atomic and grain heat, the warrant for which heat we have not in the thermometers and pyrometers, etc., or our touch, but in the metal's physical condition, weight, and atomic weight.

The most conditionally thermic of the chemical

elements are the unliquefied gases, as hydrogen. Next to them are the liquefiable gases, as chlorine. Then the liquids, such as bromine. Then the solids in their order of fusibility—first, the very fusible, as phosphorus. Then the with difficulty fusible, as platinum. And, lastly, the utterly infusible solids, as charcoal, which is thus conditionally the most athermic or the most heat negative of the chemical elements.

The hottest grained chemical elements are the lightest, such as the metalloids in general, and the grain heat diminishes with the increase of weight in the element. And the same rule holds for the atomic weights and the atomic heat.

These three heat properties are alike valuable and applicable as long as we have to do with the simple elementary bodies, but when we pass into the consideration of compound chemicals we shall find it convenient to use only conditional heat.

CHAPTER II.

HAVING thus assumed as established the existence of conditional heat in chemistry, we go on to trace the heat's behaviour during chemical combinations.

What becomes of the conditional heat of two substances when they combine chemically? It is comparatively easy to answer this question if our axioms be granted, recollected, and applied.

Let us take the metals already mentioned, and study what becomes of their conditional heat when they combine chemically with oxygen.

When the very thermic or heatful metal hydrogen combines with oxygen to form water, the hydrogen burns, loses, repels, or discharges this conditional heat. But how do we know that, under such circumstances, hydrogen loses or discharges heat? It may be thought that the great heat that we may observe during the hydrogen and oxygen combination is ample proof of heat discharge from the hydrogen; but it is by no means so, for our senses are in these matters very fallacious, and only tell us that there are heat discharges going on, but seldom their true direction; and we only know for certain that hydro-

as common heat or fire, concurrent chemical action, sunlight, electricity, nay mechanical action, etc.

Again, when solid sulphur combines with gaseous, unliquefied oxygen, sulphurous acid results, a gas liquefying under two atmospheres' pressure. We have thus solid sulphur passing from the athermic form of solidity into the thermic form of gaseity—sulphur thus most clearly gaining heat, while we have, on the contrary, oxygen passing from the more thermic unliquefied form into the less thermic liquefiable form, oxygen, therefore clearly losing heat of condition. So that when solid sulphur combines with unliquefied oxygen to produce sulphurous acid, we have a gas resulting more thermic than one of its ingredients, sulphur, and less thermic than its other ingredient, oxygen; that is, part of the heat of the more thermic ingredient, oxygen, has been transferred to the less thermic ingredient, sulphur, in sulphurous acid. So that the course taken in this case by conditional heat is that it is discharged or transferred from one of the combiners into the other: and this happens with a good number of acids.

So that during chemical combination there are at least three courses that conditional heat may take; for throughout the entire domain of chemistry no chemical combination can take place without one of the three following conditional heat changes:—

1st, This heat may be lost, discharged, repelled,

from both of the chemical combiners, as in certain oxy-metallic combinations.

2d, This heat may be gained, attracted, or discharged into both the chemical combiners, as in the bisulphuret of carbon.

3d, This heat may be lost or transferred by the one chemical combiner, and gained or received by the other, as in many acids.

And, lastly, it is highly important to be observed that conditional heat of ingredients, while they exist in chemical union, must be quite equal and alike. Thus whatever difference in conditional heat oxygen and hydrogen might have before combining to form water, when once combined and existing in water they must have the same conditional heat. For in water oxygen and hydrogen solidify, melt, vaporise, in common and at the self-same moment, and with equal ease. As components of water, the two chemical elements, oxygen and hydrogen, thermally act and suffer in unison.

So that it may be stated, shortly, that, thermally speaking, chemical combinations consist simply of conditional heat discharges and heat equilibrium. That is, conditional heat discharges from, into, or between, combining substances, leading to complete equalisation or equilibrium of the conditional heat of the combiners as they coalesce into the compound state.

Having thus succinctly traced conditional heat during binary chemical combination, we will proceed to study the same heat during the converse binary chemical decomposition. When for example the hydrogen in water is deoxidised, when that metallic oxide water is reduced or decomposed, its hydrogen, in assuming the gaseous shape from the liquid state in which hydrogen existed in the water, must have, by our axioms, absorbed heat, for hydrogen then passes from an athermic to a thermic form. Again, when mercury in the solid mercurial oxide is deoxidised, reduced, or decomposed, mercury must in assuming the liquid metallic form, from the solid form in which it existed as oxide,—mercury must, I repeat, gain heat. Mercury, in passing from its solid oxide into its metallic liquid form, has passed from thermism to athermism, and therefore mercury then gains heat.

Again, when zinc passes from its oxide shape into a metallic form, zinc passes from comparative infusibility to fusibility—that is, from thermism to athermism, and zinc must therefore, in these circumstances, gain heat; and because most protoxides are less thermic than most metals, the most of the metals gain heat in passing from protoxidicity into metallicity. This heat of condition lost and gained by metals in oxidation and deoxidation, may be conveniently called the latent heat of metallicity. A metal oxidises, and as that metal's protoxide is conditionally less thermic than the

metal itself, the latent heat of metallicity is given out or discharged. *Per contra*, a metallic oxide is deoxidised or reduced, and as a metal is conditionally more thermic than its protoxide; the heat of metallicity is taken in by the oxide metal, to enable it to assume the metallic shape. So that we have come to find out, and let it be repeated, so as to become well impressed on the mind, that every metal that combines rapidly with oxygen of the air, burns, oxidises, loses, repels, discharges heat; for example, hydrogen when it oxidises, or when changing into water, must lose heat, must become minus as to heat, for hydrogen then passes from a gas to a liquid. Out of two gases that are quite unliquefied, oxygen and hydrogen, a liquid is produced, as the result of combination. Oxygen and hydrogen must therefore, according to our axioms, have lost in this water combination great heat; a heat very evident to the senses and very great, for it is the latent heat of two of the most thermic of gases.

Moreover, hydrogen, attracting oxygen, repels heat.

Take another metal, zinc;—when zinc oxidises rapidly in air, zinc burns, loses, discharges, repels heat, becomes minus as to heat. While zinc metal is changing into zinc oxide there is a heat loss or discharge from it.

Moreover, zinc, attracting oxygen, repels heat.

But the loss of conditional heat by burning zinc is not at first sight so evident as was the heat loss in burning hydrogen just spoken of; but still we must hold that metallic zinc, like hydrogen, loses conditional heat in burning or in changing into zinc oxide, because zinc oxide is far less fusible than zinc metal, and therefore by our axioms zinc in its oxide is less thermic than zinc is as a metal, and zinc metal consequently passes from thermism to athermism in changing into zinc oxide, and therefore loses heat, becomes minus as to heat. And because by far the greater numbers of the metallic protoxides are far less fusible than their corresponding metals, we must arrive at the most important conclusion, that by far the most of the known metals, in changing into oxidity, or in burning, lose heat.

But if metals in passing into oxidity, in changing into an oxide state, in burning, lose, repel heat, it is clear that those metals cannot take the reverse step, that is, pass from oxidity into metallicity, without a gain, or attraction of conditional heat. If the change of its metallic form in a metal by protoxidation presupposes a loss of conditional heat in that metal, then this lost conditional heat must be once more attracted and regained by the oxide metal, when it re-assumes the metallic state, or is, as it is called, reduced.

In oxidation a metal loses heat, in deoxidation it gains conditional heat.

And by the study of these phenomena we learn yet more than the existence of what I have called the heat of metallicity, we observe further that a metal that is losing heat, attracts oxygen, and, on the contrary, an oxide metal that is attracting heat, is repelling oxygen, and this must be carefully remembered, as it serves to elucidate some of the phenomena of galvanism, to be described hereafter.

CHAPTER III.

PURSUING now our subject, we remark that conditional heat is a heat inherent in all bodies. This heat does not convey to our feelings any sensation of warmth or coldness. Nor does this heat affect the thermometer. Nor, what is more important, is this conditional heat lost or gained by gradual radiation or conduction from or to surrounding objects, as heat in its more familiar aspects is. But this heat is alone lost or gained *per saltum*, by a change of form in the substance losing or gaining the heat. And in this property conditional heat is entirely analogous to the latent heat, for example, of water, for latent heat in water is independent of surrounding temperature, and is neither sensible to our touch nor to the thermometer, nor is lost or gained by radiation or conduction from or to surrounding objects. But this latent heat of water is alone *per saltum* lost or gained when water changes shape by becoming solid in ice or gaseous in steam. In a like manner, the conditional heat of chemicals is alone lost or gained when substances losing or gaining it are *per saltum* changing shape during chemical

combinations. Otherwise this conditional heat is quite passive, hidden away, latent, and had never been thought to exist, or at least, as it seems to me, never attracted due attention.

But having reached the point that conditional heat can not be changed, except its changers are also themselves changed in form, the thought at once strikes the mind that, in chemical combinations, change of heat and change of form are cause and effect. In other words, that the conditional heat changes so constant and universal in chemical combinations, are what produce the form changes, also as constantly and universally present.

For we well know that simple latent heat does change the forms of matter. For example, simple heat, alone, impresses upon water such varying forms as the dewdrop, hoar-frost, iceberg, invisible steam, and the storm clouds—shapes, I venture to think, as dissimilar from each other as hydrogen and oxygen are from their compound, water. But it must be further taken into serious consideration that these heat shapes of water, dewdrop, hoar-frost, invisible steam, are by no means the only shapes that heat singly is capable of moulding upon matter. But in addition to those forms of solidity, liquidity, gaseity, given by heat, pure and simple, to many substances, we have yet another, which is not so common, and which has been called Allotropy.

A little painstaking reflection and the use of our axioms will most clearly and indisputably show, that it can only be different amounts of chemical *Heat* that give to sulphur its well-known allotropic forms.

Many simple bodies, such as charcoal, phosphorus, —nay, many compound bodies, such as the iodide of mercury, show this remarkably suggestive property of allotropy.

Of the three allotropic forms of sulphur, that which is to be obtained from crystallisation from a solution of sulphur is the most athermic, and consequently it will be the heaviest. The allotropic form of sulphur which results from prolonged heating is the most thermic, and consequently the lightest.

Of charcoal's allotropies or heat shapes, we must conclude that the diamond is the most athermic, because the diamond is the heaviest carbon.

To these changes of form, then—namely, solidity, fluidity, gaseity, allotropies—that heat is already known to give to matter, we would now add another, namely, the change of form resulting from change of our so-called conditional heat in chemical combination. And I would have it thus held that the conditional heat loss that oxygen and hydrogen have most undoubtedly suffered in forming water is the cause of the remarkable change of shape that these two gases have undergone in combining to form water. In other words, I

would have it held that water is a mixture of allotropic oxygen and hydrogen. I would have it held that to mixture and allotropy of ingredients we owe every chemical compound; mixture brought about by mutual mechanical attraction of the molecules of the combining substances; allotropy produced by the conditional heat discharges, by loss or gain of heat, by the same said molecules. When chemical compounds are taken for mere intimate mixtures of their ingredients, it may well seem marvellous and inexplicable that their ingredients should yield, by chemical union, compounds so unlike to the ingredients themselves or to those ingredients' mechanical mixture. It may well seem passing strange that chemical children alone should be so unlike their parents. But this difficulty vanishes if we know that the ingredients of every chemical compound are allotropically altered by heat changes, in addition to being mixed up together. And well we know that allotropy—that is, heat modifications—can work out miraculous changes. Singly, without any other ally or aid, allotropy can evolve the brilliantly sparkling diamond from, as it were, a piece of dark opaque charcoal. And latent heat is every day inducing in water such dissimilar but familiar forms as invisible steam, mist, and the beauteous snow crystals.

Nay, it seems certain that allotropy has far more to do than mere mixture in developing the manifold

differences observed between chemical compounds and the ingredients from which they spring. It seems thus certain, because in compounds where mixture prevails over allotropy—that is, in compounds in which there is more mixture than allotropy of ingredients, as in alloys—then the resulting compounds are, in a measure, like their parent metals. And I say that mixture of ingredients prevails over allotropy in alloys, because, in alloying, metals do not lose or gain any very large quantity of conditional heat, as is very evident from the quiet way alloying metals generally unite ; in other words, in alloying, metals do not burn vividly and violently, as they do when they combine with oxygen, chlorine, etc. etc. ; and this means that, in alloying, metals do not change enough in their conditional heat to lose metallicity and their more familiar aspects. Nay, we can even trace between the common allotropies of a substance and its combination allotropies a very strong family resemblance. Thus a good many of the metallic sulphurets are black, and there is a common allotropy of sulphur that is quite black. Solid carbonic acid is white, like snow ; the carbonates are generally white, etc. etc. And the diamond allotropy of carbon seems to exist on purpose to make us wonder less at the clear, sparkling, transparent aspect of carbon in ether, alcohol, and in many other combination allotropies of carbon.

The influences of heat in chemistry and in chemical action begin now to dawn and open upon us. It is chiefly to heat agencies that we owe the Proteian transformations so frequent in and so characteristic of chemistry.

We know, or we must grant, that radical changes of heat have the power of evolving change of form ; we know, further, that such changes of heat constantly and necessarily attend chemical combination or action : it seems a fair conclusion that the changes of heat are the cause of the changes of form in chemical actions.

Hence we will assume the existence in chemistry of a heat of transformation—a morphigenic heat.

You cool down water, suddenly, at a certain crisis, a discharge of what I venture to call morphigenic heat, but what is generally called latent heat, from the water takes place, and a change of form, of water into ice, invariably occurs. You heat the ice, and a discharge of morphigenic heat takes place into the ice, and a change of the ice's form into that of water results.

Again, you heat sulphur, and it absorbs morphigenic heat, and takes on its various allotropies. Sulphur cools, suddenly the same sulphur passes by morphigenic heat discharge into its more stable and common forms.

In nature's secret laboratory, carbon has been, by the subtraction of heat, converted into the brilliant.

You place potassium in oxygen gas, there follows an attraction of the oxygen by potassium, a discharge of heat by both potassium and oxygen, and a consequent change of shape in both, and a production thereby of a white powder. Heat now this white powder in the fierce and concentrated fire of a voltaic battery, and the heat of transformation (as will be yet more apparent in a future part of this disquisition) seizes again upon potassium and oxygen, and turns them into their pristine shapes. By adding or subtracting the heat of transformation, morphogenic heat, you have produced all these changes.

CHAPTER IV.

we have now tracked this conditional or morphic heat, this latent heat of chemical transformations, finding its loss or gain in combining bodies, during its change and equilibrium. We have also noted this heat's transforming effects on chemicals. We now pass on to investigate some of the results of an accumulation, or the reverse, of chemical heat in bodies.

A metal very chemically thermic, that is, with a considerable accumulation of heat on it, such as sodium and potassium, etc. etc., may be reasonably enough conceived, since they readily conduct heat, to have a strong tendency to cool, to emit, to discharge, to lose, to repel heat, just as all overheated bodies have a propensity to lose their surplus heat. But potassium, etc., can not, as we have seen, lose its additional heat by radiation and conduction, but only by potassium, etc., changing its form—that is, combining chemically; hence potassium and its class of metals have the utmost facility in combining, and remaining so combined; are, in fact, never found uncombined. Platinum's thermal state is quite

opposite to that of the potassium class of metals. Platinum is a chemically athermic metal. In platinum there is quite the reverse of an accumulation of heat, there is a great want, a decided lack, of heat. Platinum shall have, therefore, as it conducts heat, the strongest inclination to attract heat, as is well seen in Döbereiner's lamp, and, indeed, in many other actions in chemistry. Now, this tendency of heat attraction in platinum and its class makes platinum not easily oxidisable, for we have again and again seen that metals require to lose or to *repel* heat in order to oxidise. Platinum must be, therefore, indifferent to oxygen ; and when, by roundabout means, platinum does oxidise, platinum is with ease reduced from its state of oxide, for gain of heat is easier to platinum's character and nature than loss of heat ; for platinum is a metal altogether chemically athermic, by weight, fusion point, and atomic weight.

We have ere now found that a metal, in order to oxidise, must repel heat ; hence such metals as thermic potassium, etc., that best repel heat, shall clearly best oxidise ; and such metals as athermic platinum, etc., that best attract heat, shall be the very worst to oxidise. Again, we found, also, that a metal, in order to deoxidise, must attract heat : hence such metals as athermic platinum, that best attract heat, shall best or easiest deoxidise,

or be reduced ; while that metal which most attracts heat, as thermic potassium, shall, *ipso facto*, be the very worst to deoxidise. If you heat a metal artificially, you of course accumulate more and more heat upon it, and are thereby, all the time your heating continues, increasing more and more the heated metal's tendency to cool, to discharge, not only the heat you are adding to it, but the metal's own conditional heat. You are increasing the metal's tendency to discharge heat, that is the metal's tendency to combine chemically ; for example, to oxidise, and oxidation, therefore, at a determinate crisis is sure to happen,—in this manner, of a sudden, there occurs a rapid change in the metal's and oxygen's conditional heats, this being visible to us as a flash of light and heat, and oxygen and the heated metal simultaneously lose, discharge heat, and change their forms, and in fact combine ; all which passes with the rapidity of an electric phenomenon. Indeed, if heat be the cause of chemical transformation, as I would have it to be, the more thermic a metal inherently is, or the more thermic you artificially make it, the readier will that metal be to chemically transform, or to combine. We have thus seen or thought that one of the effects of a body's being chemically overheated, was that thereby that body had a great inclination to cool, as all bodies overheated in the common way are well known to have. Hot bodies wish for cold ; hot bodies, if I may

be allowed the expression, attract cold, and therefore the substances that are cold or athermic. We have imagined, further, that one of the effects of a body's being chemically cold, was, that that body had a tendency to attract heat, and therefore the bodies that are chemically heatful or thermic; we therefore come to the conclusion that chemically thermic bodies will mechanically attract athermic bodies: that chemical substances, in opposite or different states of heat, mechanically attract each other—the athermic chemicals mechanically attracting the others that are thermic, and, *per contra*, the thermic chemicals mechanically attracting those that are athermic.

In order to prove that it is the difference in the heats of chemicals that is the cause of the chemicals' mutual mechanical attraction, we require to examine carefully the heats of typically attracting chemical substances, such as the metals and the metalloids, the acids and bases,—using for this examination the axioms of which we stipulated the concession, and of any other heat effects that shall be suitable.

On examining, by means of our axioms, the heat states of the metals, and of those metalloids that are known to attract them, we *do* most clearly find that the metals are, as a class, chemically athermic, while the metal-attracting metalloids are chemically thermic.

For, excepting the very exceptional metal hydro-

gen, there are only four of the most conditionally thermic of the metals in nature—namely, mercury, rubidium, potassium, sodium—that are more thermic conditionally than the most athermic of the metal-attracting metalloids, sulphur and iodine. For mercury, rubidium, potassium, sodium, alone of the very many metals, have lower melting points than the most athermic of the restricted group of metal-attracting metalloids, sulphur and iodine.

But mercury's great grain athermism, as shown by mercury's great weight, and mercury's great atomic athermism, as shown by mercury's large equivalent weight, throw mercury completely out of the class of thermic metals proper, that can be at all compared with the metalloids. So that only three metals, rubidium, potassium, sodium, out of upwards of forty metals, are a little conditionally more thermic than the most athermic, mark you, of the metal-attracting metalloids, sulphur and iodine. Hydrogen alone of all the metals presents a most distinct and startling exception, for, as far as we can by our axioms judge, hydrogen is the most thermic substance in nature.

The metal hydrogen, therefore, instead of being at all athermic, is intensely thermic. One sort of explanation of this most exceptional nature of the metal hydrogen may however be attempted. Hydrogen's great lightness (it is by far the lightest form of matter known) ; hydrogen's very small atomic weight (it has

by far the smallest atomic weight of known bodies), show or indicate such enormous powers of heat concentration in hydrogen, such susceptibilities to heat in hydrogen, that we must consider even the gaseous state to be a very athermic state for such a hot grained and atomized metal as is hydrogen. Hydrogen has such heat capabilities, that hydrogen, the gas that exists here in this planet, is cold indeed when compared to the state in which it may exist elsewhere, as in the sun for example.

But placing, in the meanwhile, aside the exceptional metal hydrogen, we repeat that it takes the heat of the exceptionally most thermic of the many metals to match the conditional heat of the exceptionally athermic of the metal-attracting metalloids, though comparatively few in number. And if we, on the contrary, take the most thermic of this metalloid group, oxygen, and contrast oxygen's heat with that of one of the more athermic metals, platinum, the heat difference is enormous. We have therefore most decidedly the metal's conditional states as to heat not only different, which might suffice for weak mechanical attraction, but the opposite to that of the metal-attracting metalloids, which produces that strong mechanical attraction known to exist. The metals are thus minus as to conditional heat, and the metal-attracting metalloids plus as to that heat.

If we also contrast the weights, or the specific

gravities of the metals with the weights of the metal-attracting metalloids, we shall find that the metals are, as a class, heavier than the metal-attracting metalloids. For it takes the lightness of the exceptionally light metals, potassium, etc., to match the lightness of the heaviest, mark you, of the metal-attracting metalloids, iodine namely. There being out of about forty metals only eight that are lighter than the heaviest of the comparatively few metal-attracting metalloids, iodine. So that by the test of weight the metals are, as a class, colder grained than the metal-attracting metalloids ; the metals are minus as to heat, and the metalloids plus as to heat.

Again, if we contrast the specific heats of the metals with those of the said metalloids, we shall find that the metals, as a class, are colder specifically than the metal-attracting metalloids. For, excluding iodine and bromine, there are only five or six metals of the forty that are specifically hotter than the metal-attracting metalloids. So that by the test specific heat, also, the metals are as a class atomically less thermic than the said metalloids.

So that we have found that by the three great tests of condition, weight, and specific heat, the metals are as a class chemically less thermic than the group of metal-attracting metalloids. We say as a class, for among the most thermic metals and athermic metal-

loids, examples may be taken whose heat or thermism is pretty much alike, and which thus form a mid-way group that connects the heat properties of metals with the heat properties of a certain group of the metalloids.

In fact, nature so acts always, there seldom being any abrupt passage, but on the contrary a gradual imperceptible transition from one group of substances or animals to another. And it is interesting to note that the metalloid iodine, that has heat properties—that is, that has condition, weight, and above all, specific heat most similar to the metals—is actually very like on superficial examination to a metallic substance. So that, if our axioms be granted and be true, there can not be the slightest doubt that there is not only a chemically heat difference but a heat contrast between metals and the metalloids that so readily and powerfully attract them, the metals being negative as to heat if contrasted with the metalloids, which are plus as to heat.'

But there is yet another and a most important heat contrast between metals and metalloids, and that is simply that the metals conduct heat and the metalloids do not, so that there exists between these two groups of chemicals a heat-conduction contrast.

Again there exist other metalloids that do not attract the metals, and this group of metal-repellant

metalloids consists of carbon, silicon, boron. Testing the conditional heat of this group by our axioms, we find these metalloids conditionally cold, and indeed one of them, carbon, is the coldest element known, inasmuch as carbon has never been unequivocally fused. So that it would seem that comparative opposite states of heat produce attraction, and comparative similarity of conditional heat produces chemical repulsion. That is, that a plus or positive state as to heat attracts the minus or negative state as to heat, and that minus or negative state as to heat repels the like minus or negative state as to heat.

If we scrutinise the thermal states of acids and bases, we find most distinctly that these great groups of chemicals are in opposite states of heat—the acids being decidedly thermic, and the bases athermic.

And, first, taking the inorganic acids for study, and beginning at the very root of the matter, we observe the ingredients from which those acids spring, and find them derived exclusively, or in greatly preponderating proportions, from metalloids—that is, from the thermic group of the elements. Thus the ingredients of what are called the hydrogen acids consist of the thermic metalloids, chlorine, bromine, etc., and hydrogen, the most thermic substance known; as, for example, hydrochloric acid, hydrobromic acid, etc.

The ingredients of the most powerful of the oxy-acids are very often wholly derived from metalloids, or the thermic group of the elements, such as, for example, sulphuric acid, nitric acid, etc.; and even in the metallic oxy-acids, the quantity of that very thermic metalloid, oxygen, vastly preponderates over the athermic metallic ingredient of the acid, as in permanganic acid ($\text{Mn}_2 \text{O}_7$), antimonie acid ($\text{Sb}_2 \text{O}_5$), etc. etc. So that it is quite evident that the acids come from the thermic group of substances. But it is clearly not enough to prove the thermic state of the acids that we observe the fact that these acids spring from thermic parents, for these thermic or heatful parents might, in combining to produce the acid, lose all their heat—that is, suffer complete thermal degeneration. We must, therefore, prove further that the inorganic acids not only spring from thermic parents, but that these thermic parents transmit their heat to their acid offspring. And this we easily do by noting the course taken by conditional heat during the formation of inorganic acids. If we examine, therefore, the thermal phenomena of the acid's formation, we find that at least one of the acid's components gains heat of condition in the act of forming the acid. For example, the hydrogen acids are composed of the thermic chlorine, bromine, etc., and the more thermic hydrogen. When now chlorine combines with hydrogen to produce hydrochloric acid,

part of the heat of the more thermic component hydrogen passes into the chlorine, for hydrochloric acid is a gas more thermic than chlorine, and less thermic than hydrogen, for hydrochloric acid is a gas liquefiable at 40 atmospheres, chlorine at 4 atmospheres, and hydrogen is unliquefied. The gas hydrogen therefore being farthest from liquidity, the gas hydrochloric acid next, and the chlorine nearest to liquefaction, it follows that hydrogen is the most thermic, and chlorine the least thermic of these three gases, hydrogen, hydrochloric acid, and chlorine. So that in this combination of the thermic hydrogen and chlorine there has been not a heat degeneration, but a heat transference from the more thermic to the less thermic ingredient. The same heat transference from hydrogen takes place into bromine when the two combine to form hydrobromic acid, for we find liquid bromine becoming a gas in hydrobromic acid. Bromine thus retaining part of the heat of hydrogen when the two become an acid ; the same thing happens with iodine.

In some oxy-acids, analogous heat transferences from a more thermic into a less thermic ingredient, the same heat retention takes place. Thus the heat transference from oxygen into solid sulphur raises sulphur into an acid gas—the sulphurous acid, a direct compound of oxygen and sulphur. The same thing happens with carbon in carbonic acid gas, etc.

But as a general rule the thermal phenomena are different with the greater part of oxy-acids. The most of the oxy-acids are not direct compounds of oxygen but a compound of water and a radicle anhydride. Thus sulphuric acid is a compound of water and a solid white fibrous mass (SO_2) that is without the slightest property of an acid. This solid SO_2 through long water combines with it, and assumes the liquid form—that is, undergoes a chemical transformation from an anthermic to a thermic form; in other words gains heat. One of the ingredients of sulphuric acid—that is, the solid anhydride—has therefore clearly gained heat in becoming acid. The same thing happens with nitric phosphoric acid, and with most of the typical powerful inorganic oxy-acids, whose radicles or whose anhydrides can be isolated. In the case of the acids whose radicles have not as yet been isolated, we are entitled to consider by analogy that it would be so, if these radicles or anhydrides were isolated. Some irregular, feebler acids prove exceptions; but then these acids are so exceptional themselves as not to invalidate the general reasoning.

Now, if inorganic acids spring from hot ingredients which suffer little thermal degeneration, it follows that these acids must be, as a general rule, in a conditional thermic state, and this we find to be the case. For if we examine the acids' conditional heat states,

we find that by this test the acids are thermic conditionally. For the inorganic acids are, as a class, either gases or volatile liquids, or fixed liquids, or soluble or fusible solids, each of these forms belonging more to the thermic side of our chemical thermometer than the athermic.

So that there exists in an acid's origin, formation, and condition, conclusive evidence that the acid is chemically thermic. But it is clear that acids can exist in a wide range of conditional or physical states. No doubt acid nature must always prefer the more thermic physical states of matter, but still a comparatively athermic conditional state is not quite incompatible with acidity, or with acid properties. In illustration of my meaning, let us take the gases hydrochloric acid, hydrobromic acid, and hydriodic acid, and we find these three substances have different conditional heats. Hydrochloric acid being farthest from liquefaction, is the most thermic conditionally of these three, and hydriodic acid the most athermic. But, nevertheless, conditionally athermic hydrobromic acid is an acid quite as well as its more thermic *confrère*, hydrochloric acid. For, in point of fact, both hydriodic and hydrochloric acids have the same quantity of the heat of acidity got from their ingredient, hydrogen. But gaseous chlorine being more thermic than solid iodine, of course thermic chlorine, after receiving hydrogen's heat, will be more thermic than

the athermic solid iodine after receiving the same amount of heat from hydrogen—that is, hydrochloric acid will be more thermic conditionally than hydriodic acid ; for in the case of chlorine, hydrogen, to form hydrochloric acid, discharges heat into a gas, chlorine ; into a substance, namely, already by nature thermic or heatful, and in the case of iodine, hydrogen, to form hydriodic acid, discharges an equal amount of heat into a solid, iodine,—into a substance, therefore, by nature athermic or heatless. But as both chlorine and iodine receive from hydrogen, in their compounds, hydrochloric and hydriodic acids, a certain amount of heat, in addition to their own proper heat, chlorine and iodine, become then acid. So it is this heat of acidity, and not the heat of condition of a substance, that makes it an acid. Substances having this heat of acidity in their molecules, or getting this heat added to it in any way, will become an acid, but not till then. For example, silica's usual physical condition is by no means that of a normal acid, and silica only becomes an acid when it obtains the heat of acidity in a hot furnace, etc.

The inorganic bases form a striking heat contrast to the inorganic acids. By far the most of these bases have one ingredient belonging to the athermic metallic group of substances. The other ingredient of the base may come from the thermic metalloids,

but it is a highly remarkable fact that the less of the thermic metalloids a base has the better base it is.

But to prove the athermic state of a base it is by no means enough to observe the fact that bases spring from athermic parents, for those athermic parents might, in combining to produce the base, gain heat. We must therefore not only prove that bases spring from athermic parents, but that these parents do not acquire heat as they produce their offspring, the bases. And we are thus forced to examine the course taken by conditional heat during the formation of a base. But bases are formed from the combination of metals with oxygen from protoxidation of the metals. And we have ere now pointed out that in protoxidation of metals both the oxygen and the metal lose, discharge, repel heat. So that both the ingredients of a base, in forming the base, lose heat of condition. So that bases are, by origin and formation, athermic. But if bases spring chiefly from athermic ingredients, which, in addition, suffer still further thermal degeneration in combining to form the bases, it follows that bases must, as a rule, be in a conditionally athermic state. And this is, in fact, the case, for if we examine the bases' conditional state we find them athermic, for they are, as a rule, badly-fusible, or insoluble solids.

But it is clear that bases may exist in a wide range of conditional or physical states. No doubt

but that base nature must always prefer the more athermic physical states, but comparatively thermic physical states are not incompatible with basic powers or properties. To illustrate my meaning, let us take the three bases—ammonia, potassa, and the oxide of zinc—and we find that these three substances have each very different conditional heats. Ammonia is a gas, potassa a soluble solid, oxide of zinc an insoluble solid—ammonia being therefore the most thermic, and oxide of zinc the most athermic of the three; but thermic ammonia is a good base as well as athermic oxide of zinc, for, in fact, all the three metals—hydrogen, potassium, and zinc—in ammonia, potassa, and oxide of zinc, have each lost a large amount of basic heat. In each of these three metals there is a large basic deficit or lack of heat, and therefore these metals have their basic allotropies. But as hydrogen, when it began to lose heat to become a base in ammonia, was an unliquefied gas, hydrogen's basic heat loss only reduced hydrogen in ammonia to an allotropy liquefiable at 6 atmospheres, while, of course, solid zinc's basic heat loss reduced the comparatively athermic zinc in the oxide of zinc almost to infusibility. For basic athermism is not exactly conditional athermism, for it is reckoned from the heat states of the bases' ingredients before combination, and not, as is conditional heat, from distance from liquidity. Hence it arises that ammonia is

a gas, and still a very powerful base, for in ammonia there is a most distinct basic heat deficit, for ammonia's ingredients—nitrogen and hydrogen—are unliquefied, and ammonia itself liquefies at 6 atmospheres, and solidifies at minus 103° . Ammonia is athermic if you compare it with its very thermic progenitors. So that we come to find that it is more the basic heat loss, and not actual conditional heat, that forms the base. So that we will assume in the course of this paper that inorganic acids and bases are in opposite states as to heat—that acids are plus or positive as to heat, and bases minus or negative as to heat. But we cannot, in a review of acids and bases, entirely omit those of organic chemistry. In studying these delicate and highly complex structures, so eminently sensitive to heat, we at once perceive that our already enumerated heat tests are far too coarse for such cases. But the effects of heat on matter are so numerous and pronounced, and as we shall freely adopt and use any and all heat effects that may suit us, we shall, I hope, have but little difficulty in finding other suitable chemical thermometers for organic chemistry.

Now, we know that heat influences the solubility of substances, as a rule, by increasing solubility, so that we will assume that a soluble substance is more thermic conditionally than an insoluble one, for solubility seems to be akin to fusibility. And if we admit this assumption we at once see that the organic acids

are, as a rule, more thermic conditionally than the organic bases, for the organic acids are much more soluble than the organic bases.

In connection with this subject, and for our future use, it is interesting to note that the taste of positive electricity is acid, and the taste of negative electricity is alkaline. And, in those days of spectral analysis, it may be noted that the colours red and green given by acids and alkalies to certain vegetable colours are the acid red colour, the hot colour of the solar spectrum, and the alkali green colour, the cold colour of the solar spectrum.

CHAPTER V.

IN recapitulation: we began this subject by calling attention to the great importance of heat in chemistry. We then pointed out that each element possessed its own peculiar, inherent, conditional, atomic and grain heat, measured by the element's physical state, weight, and atomic weight. We then showed that this heat, or at least conditional heat, was changed by chemical combinations in one of the following three different manners:—Conditional heat was discharged *from* the combiners, or was discharged *into* the combiners, or, finally, was discharged or transferred from one of the combiners to the other. And that from these heat discharges there resulted a heat equilibrium in the compounds produced. We found, further, that as their conditional heat was changed the shapes of the combiners as constantly changed, so that we inferred that the *heat* change was the cause of the *form* change in chemical combinations. And we stated that chemical transformations were not only not unlike the other and more familiar or acknowledged transformations that common heat produced on substances, but were quite

similar or identical with allotropy. We assumed, therefore, that chemical compounds were mixtures of allotropies of their ingredients. Mixture the result of attraction, and allotropy the result of heat changes, in the ultimate molecules of combining ingredients. We thus reasoned out the existence in chemistry of a *morphigenic heat*, a heat of chemical transformations.

We then went on to examine some of the effects of heat's accumulation or its deficiency in chemicals, and we thought we found that when bodies were too thermic, as potassium, they had a tendency to cool, to repel, to discharge their heat—to attract cold or athermic chemicals. When, on the contrary, bodies were too athermic, as platinum, they had a tendency to get more thermic, they attracted heat or hot chemicals. So that we concluded that thermic chemicals attracted athermic chemicals, and *vice versa*—that is, that attracting bodies in chemistry were always in a different, or if they attracted each other very powerfully, in an opposite state of chemical heat. And this we carefully tried to prove to be the case with metal and metal-attracting metalloid, with acid and base.

So that we have come to reason out that when chemical substances combine they must be first in different or opposite states as to heat, in order that they may mutually and mechanically attract. In the second place, the combining substances must

change their conditional heats, and therefore their forms. And lastly, that this change of heat must be so contrived and ordered that there shall be a heat equilibrium in the new compound.

We are now in the possession of the three steps of which chemical combinations consist, and are therefore much better able to understand how such chemical combinations come about; we repeat that chemical combinations consist of—

- 1st, Difference in conditional atomic and grain heat—viz., in chemical heat producing simple mechanical attraction, and leading to—
- 2d, Heat changes, or heat discharges, causing shape changes, terminating in—
- 3d, Equilibrium of heat, bringing about certain effects hereafter to be noted.

All these steps must be taken concurrently, or in very rapid sequence, by the substances that combine chemically. However decided any single one, or even two, of these three steps may be, still no chemical action can take place unless the whole three steps be *seriatim* taken. I mean that to combine chemically, substances must mutually mechanically attract. But this is far from being enough. These combining substances must further change their conditional heat. But even this is not enough. These said substances must change heats in such a way as to produce a heat equilibrium, as to assume equal conditional heats in their compound states.

In order to illustrate my meaning, let us anatomise carbon's thermal properties. Carbon is conditionally the most athermic of all known elements, but carbon's lightness and light atomic weight show carbon to be a very hot grained and atomed substance ; hence the athermism must be an intense one that can produce utter infusibility in such hot grained material as is carbon. This very intense conditional athermism is what probably produces carbon's great hardness in the diamond, and carbon's complete insolubility in all known menstrua. Platinum, though with difficulty fusible, cannot be so athermic as carbon. For platinum's heavy weight and atomic weight indicate that platinum is a cold grained and atomed metal, so that the athermism that will make cold grained platinum infusible need not be so great as carbon's cold. Carbon, I repeat, is an exceedingly conditionally athermic body, but it conducts heat ; carbon is therefore both willing and able to heat itself ; that is, carbon must mechanically attract those thermic bodies that can furnish it with heat. Carbon must and does mechanically attract thermic bodies ; it draws and condenses into its pores with great power the heatful or thermic gases. Indeed, from the mechanical adhesion of the gas hydrogen, in certain cases, carbon can with great difficulty be freed. But this very athermic conditional state of carbon that makes it so ready to attract mechanically its opposite, *the thermic bodies*—this athermic state of carbon

unfits it to take the second step in chemical combination, renders carbon unable readily to change its form, for change of form is to be brought about by heat; hence carbon, if you do not meddle with its temperature, is the most inert of chemical substances. You must, in fact, heat carbon a good deal to empower it thereby to undergo chemical transformations, that is to combine. Carbon's natural state is, as it were, the same as the artificial state of antimony when cooled by Schrötter to minus 106° ; but carbon's lightness, small atomic weight, conduction of heat, prove it, as we have said, a hot grained and hot atomed metalloid. That is, that carbon has great susceptibilities for heat, considerable powers of being heated. And so the heat you give carbon easily affects it, is readily accumulated in it, and thus produces heat effects better in carbon than platinum, which we have found is quite athermic, by weight, atomic weight, and condition. In the textural particles, in the recondite atoms of platinum, there is little sign indeed of power in platinum for any kind of heat concentration; thermic bodies will therefore eagerly enough seek platinum's coldness to discharge there the superabundance of their heat, that is to get there cooled, and platinum will, *per contra*, seek these thermic bodies to be by them heated. So that, conditionally, athermic spongy platinum draws and condenses in its pores with great power the thermic

gases, just as the similarly athermic carbon did. And platinum is thus ever ready to take, and indeed ever taking, the first step in chemical combination, that of mechanical attraction. But platinum's thorough athermism makes platinum woefully incapable of taking the second step in chemical combination, that, namely, of form changing, for form changes are alone to be effected by heat. And although platinum's athermism will make it always attract heat, still platinum's athermism is such that no heat that platinum has a chance of readily attracting is, as a rule, sufficient to make platinum's conditional heat reach its point of discharge, or give platinum its combination allotropies, for platinum is an athermic or heat negative metal, by weight, atomic weight, and condition. There is thus a complete contradiction in the heat properties of carbon ; carbon seems at one and the same time very athermic and very thermic, for carbon is very athermic conditionally and very hot grained, and one of the hottest atomed bodies in the world. But it is only by this very heat contradiction that we can at all explain the corresponding contradictory chemical behaviour of carbon. For carbon is, on the one hand, owing to its great conditional athermism, the most unalterable and inert of chemicals in nature, and, on the other hand, owing to carbon's very great atom and grain heat, and heat conduction, carbon becomes the most active among *the elements*. Carbon, I repeat, is the most un-

changeable of the elements, and the cause is evident; it is because Nature, as it were, has cooled down carbon in her own solid carbonic acid and ether bath; Nature has given very great conditional athermism to carbon; but it is clear that this chemical heat defect of carbon is of all chemical heat defects the easiest remediable by art, for we can easily enough heat carbon, and as carbon conducts heat well and is already hot grained and hot atomed, this single heat defect of carbon, that is carbon's conditional athermism, is readily done away with, and carbon thus ranks with the thermic chemicals. Nay further, this very great conditional athermism of carbon is of extreme value in producing that perfect mechanical attraction, that first great indispensable in chemical combinations that we see between thermic oxygen, thermic hydrogen, and thermic azote, and athermic carbon, in organic chemistry.

In the heat properties of the metal quicksilver, there appears also complete contradiction, but the reverse of carbon. For carbon is very athermic conditionally, and very hot atomed, and very hot grained. Quicksilver is very thermic conditionally, and very athermic in grain and in atom. But quicksilver's double heat defects, that is its great weight and atomic weight, are not so amenable to treatment or cure artificially. For it is clear that we are unable by art to increase or diminish at will the atomic

weight of quicksilver. So quicksilver ranks permanently, by its great weight and atomic weight, among the athermic and noble metals, having, however, chemical properties that clearly result from quicksilver's great conditional heat. So that we have now glanced at the thermics of a substance carbon, that was, as it were, thermic on one side and athermic on the other ; and secondly, of a substance, platinum, athermic on all sides ; and thirdly, of a substance, quicksilver, athermic in some things, thermic in others ; and it is observable that the above enumerated heat properties affect the chemical acts or behaviour of the said substances possessing them in a correspondingly remarkable manner.

We now pass to examine the thermics of a metal that is in every respect thermic, the metal hydrogen.

Hydrogen forms a striking thermal contrast to platinum, for hydrogen is thermic by weight, atomic weight, and condition. And as hydrogen is thus the antipodes to platinum in heat properties, so are the two also the very antipodes of each other in their chemical properties. Hydrogen has great chemical powers, it enters into the formation of an infinitude of organic compounds ; hydrogen enters into direct and indirect chemical combinations with the utmost promptitude. Platinum is the most permanently sluggish of the elements.

Although hydrogen forms with oxygen the very

the compound that is called water, still hydrogen and oxygen may be kept intimately mixed for an infinite time, without at all combining. This arises from the fact, that these two gases are both very athermic, are *both*, when they combine to form water, going to discharge heat. This they must do, as we have seen, if they so combine, either into each other, or into the air. But as all these three—the atmosphere, oxygen, and hydrogen—are almost equally athermic, hydrogen when wishing to combine with oxygen to form water, that is hydrogen when wishing to discharge heat, meets with a difficulty, for neither oxygen nor the surrounding air can readily act as a conductor away of heat or a refrigerator to hydrogen. Hydrogen is therefore, as it were, glad to get the very athermic metal platinum to do this service for it, and in the presence of platinum the two gases, hydrogen and oxygen, combine much more readily, for these gases can then discharge the heat they do not want, and are repelling upon the extremely athermic platinum longing for or attracting this heat or any heat. And in these circumstances, the platinum, by attracting the heat, becomes white hot. So that, in the case of the gases oxygen and hydrogen, it is the second step in chemical combination that is difficult—namely, the heat discharges, the form changing. The fact that oxygen and hydrogen (it is the heat seen in the oxy-hydrogen blowpipe) have got to lose in com-

bining is so enormous that they find a difficulty in getting, so to speak, rid of it.

So that, as we found in the case of carbon, there was from lack of heat a difficulty in changing form, so we now find that too much heat in hydrogen impedes somewhat heat discharge and shape change in thermic hydrogen. But as this very thermic state is the only heat defect of hydrogen, and as hydrogen conducts heat, the defect can be easily remedied by presenting to hydrogen and oxygen about to combine, and wishing therefore to lose heat, a very athermic object, a strong heat attractor, as platinum. Just as we had to heat athermic carbon to make it combine, we have to cool thermic hydrogen in order to make it readily combine, and as both carbon and hydrogen conduct heat, this is not difficult ; and thus the reason that utterly athermic platinum produces at once quiet union of the two gases oxygen and hydrogen, is, that platinum athermises them. So that we have come to note in chemistry that the opposite extremes of conditional temperature—the very thermic, such as hydrogen, and yet more, the very athermic, as carbon—have their especial difficulty in form change. The state of liquidity being clearly the most favourable to chemical action, and therefore what is called by chemists the nascent state, which is almost invariably a liquid allotropy of the nascent body, proves of great and daily use in procuring the

indirect union between certain chemicals. For in the nascent state this difficulty of form change is lessened, obviated, or evaded, and the mechanical attraction often produced or at least increased or facilitated.

That chlorine should have greater ease in combining with hydrogen is easily enough conceived: chlorine is perceptibly less thermic than hydrogen, and therefore will attract mechanically the hydrogen better than oxygen did.

It requires more circumlocution to explain why hydrogen does not combine with most of the metals, say with aluminum, as hydrogen does with bromine, etc. etc. For aluminum is less thermic than hydrogen, and aluminum is far from being so athermic, conditionally, as to make it difficult for aluminum to change form. Why do not aluminum and hydrogen combine? It is because aluminum and the metals, as a rule, have no allotropy that at all corresponds with any that hydrogen can have. The metals and aluminum with hydrogen cannot fulfil the third condition of chemical combinations—namely, the equilibrium of heat. For we have most distinctly seen that three things are necessary for chemical combinations—viz., Difference of heat, Heat changes, and finally Heat Equilibrium; that is, the assumption of equal heats in their compounds by ingredients. Without the complete and perfect concurrence of

these three conditions, no chemical union can ever take place.

Now the metals, say aluminum and hydrogen, have clearly sufficient difference between their chemical heats to make them mechanically attract, and both have readiness enough to change forms; but hydrogen and aluminum cannot assume equal conditional heats; there is no equilibrium of heat in any allotropy that the two can together take; there is no good fellowship in any of their heat shapes. And besides, between hydrogen and the other metals there does not exist the great heat contrast of conduction and non-conduction of heat. But in order to see plainly the inequality of the combination allotropies or heat shapes of hydrogen and the other metals, let us very briefly examine the heat shapes that hydrogen seems capable of assuming in its varied compounds, recollecting always that hydrogen is the lightest of substances, having the smallest of atomic weight, and the very highest of conditional heats, and accordingly prepared to find traces of this great heat throughout most of hydrogen's glow shapes or allotropies. In combination with oxygen in water, the allotropy of hydrogen is fluid, and a fluid of very great solvent powers. With chlorine and its allied groups of metalloids, the heat forms of hydrogen are gaseous, as also with sulphur, phosphorus, etc. With oxygen and carbon in organic chemistry, the allotropies of hydro-

gen show no similarity to those of the metals. Examining now the allotropies of the metals in combination, we find them, as a rule, very different indeed from those of hydrogen. With oxygen the metal's heat shapes are solids, some of which, as lime and yttria, are utterly infusible, and many are insoluble and badly fusible. The combination allotropies of the metals with chlorine partake also more or less of the same nature. So that it would seem that this marked difference in their combination allotropies, aided perhaps by the absence of the heat contrast of conduction and non-conduction of heat, impedes the union of hydrogen with the metals. But it is interesting to note that ready volatility in certain metals seems to enable them to give allotropies to match those of hydrogen, and therefore fits them to enter into chemical combination with hydrogen, as happens with arsenic and antimony. And it is worthy of note also that in these metals, arsenic and antimony, the heat contrast of conduction and non-conduction of heat also, to some extent, occurs. Chemical combinations seem therefore much more complex than was supposed, and are not to be clearly and satisfactorily explained by the somewhat vague terms of chemical affinity or attraction. Chemical combination, it must ever distinctly be borne in mind, consists in mechanical attraction, it is true, but also in transformation and heat equilibrium. And it is not every substance

that possesses the capabilities of completely and easily fulfilling all these three rather complicated and inexorable conditions.

Oxygen alone seems to be thus happily constituted ; oxygen is very thermic ; I take it that oxygen is the most thermic element but two, nitrogen and hydrogen. Every element except fluorine is known to combine with oxygen. For oxygen's heat fits it admirably for chemical transformations, and oxygen's allotropies are thus marvellous. For oxygen occupies, as far as we can by our axioms judge, the middle place among the most thermic elements in the following order : Hydrogen, Nitrogen, Oxygen, Chlorine. Hence oxygen's conditional heat, weight and atomic weight, are such as at once suit both the heat properties and allotropies of the most thermic and athermic elements. In oxygen, and in oxygen alone, are thus united in the greatest perfection the properties and powers of a puissant chemical.

Of the three unliquefied elements, nitrogen is the most peculiar and the most difficult perhaps to understand. We require, therefore, to inspect with care and minute attention the heat properties of nitrogen, as compared with those of its two brother thermic elements, oxygen and hydrogen. Of these three we have often observed that hydrogen is the most thermic in all respects. For hydrogen is the lightest, its weight being 0.0692, and has the smallest

atomic weight, its atomic weight being 1, and it is doubtless the farthest from liquefaction, inasmuch as hydrogen is the least soluble in water of these three gases. Nitrogen comes next, for nitrogen is next to hydrogen in lightness, having 0.9713 as its weight; next to hydrogen in atomic weight, for nitrogen has 14 for its atomic weight; and in all probability next to hydrogen in conditional heat, for nitrogen is soluble in 50 parts of water. Oxygen comes last, for oxygen is 1.1057 in weight, and has 16 for its atomic weight, and is soluble in 25 parts of water. But when we reflect that nitrogen has but a $\frac{1}{14}$ of the specific heat of hydrogen, and many times the specific gravity of hydrogen, we at once perceive that nitrogen is a very cold grained and atomed substance if compared with hydrogen. And further, nitrogen does not conduct heat. So that it is a far greater feat for Heat to raise such a cold grained substance as nitrogen to the conditional heat pitch that nitrogen has, than for Heat to raise hydrogen to the heat pitch that hydrogen has; in other words, hydrogen conducting heat, and already hot grained and atomed, is not so difficult to heat up as nitrogen, which is comparatively cold grained and atomed, and does not conduct heat. Viewed in this manner, nitrogen becomes in some sense comparatively the most thermic substance in the world. In fact, everything indicates an intense attraction for heat on the part of nitrogen, for it

exists almost unchangeable in the most thermic of states in this planet as four-fifths of our atmosphere. Moreover, we see that nitrogen parts with the principle heat with extremest reluctance. For example, the compounds that nitrogen forms with oxygen, and in which nitrogen at all preponderates, as in N_2O and NO , the protoxide and deutoxide are all very thermic; and it is only when the oxygen part of these nitrogen compounds begins decidedly to preponderate, as in N_2O_3 , N_2O_4 , N_2O_5 , nitrous acid peroxide and nitric acid, that nitrogen is forced, dragged, overborne by its partner oxygen, to the assumption of athermic forms. If, therefore, nitrogen is so fond of heat, we would expect that it should attract again any heat parted with, particularly if it be a comparatively small amount, with extreme violence. And this we seem to see in some of nitrogen's very explosive compounds. In fact, nitrogen acts by heat as carbon acts by cold. Nitrogen is very conditionally thermic in spite of comparative atomic coldness, and carbon is very conditionally athermic in spite of atomic heat; and it is interesting to remark that it is with very athermic carbon that the heat of nitrogen is balanced, and a strange gaseous compound produced, presenting all the characters of an element of the metalloid or thermic type, that is cyanogen. It is also most noteworthy that this very thermic substance, nitrogen, enters largely

into the formation of organic beings, and all the more largely as the complexity and high development of grade of these beings increases. And also that nitrogen is a conspicuous element in some of the most deadly and dangerous of poisons. It is further remarkable that in organised structures the very thermic substances, nitrogen, hydrogen, and oxygen, all occur in forms much less thermic than when free, the action of 'organised tissues being to extract heat from its storehouses, these thermic substances, for the purposes of life, the heat of life. So that these hot elements, hydrogen and nitrogen and oxygen, are more related, as it were, to life, nearer to life, or, so to speak, more alive, than the colder elements, such as platinum, etc.

The heat properties, that is weight and specific heat, in oxygen and nitrogen are very similar, and both do not conduct heat, and both are very conditionally thermic, and this similarity of chemical heat prevents completely a violent mechanical attraction between the two ; that is, free oxygen and nitrogen must perform very badly the first step in chemical combination, that of mechanical attraction ; and hence it arises that these two gases remain mixed in the atmosphere without any attempt at chemical combination,—they have not the necessary mechanical attraction for combination—they cannot take even the first step towards combination.

It is little use to present to them an athermic object, as we did to hydrogen and oxygen, for they do not conduct heat; nor does nitrogen wish to discharge much heat when it combines with oxygen to form its protoxide and its deutoxide—the former being a thermic gas very difficult of liquefaction, and the latter still unliquefied. And it is only, as we have said, when nitrogen's nature is, as it were, so far modified and overmastered by a great excess of the more heat-plastic oxygen, that nitrogen assumes the solid form in nitric acid anhydride. So that nitrogen only discharges heat when mixed with a large excess of oxygen; but then in the atmosphere it is just the reverse, for there is a very large excess of nitrogen compared with the oxygen.

So that we thus seem to have some explanation of the stability of the composition of our atmosphere.

The thermal properties of nitrogen, as far as known, place nitrogen between oxygen and hydrogen in the heat scale.

So that nitrogen ought to have, on the one hand, some of the characteristics of oxygen and its compounds, and, on the other hand, some of the chemical characteristics of hydrogen and its compounds; and this seems in a measure to be the case, for the heat shapes of nitrogen are somewhat like those of hydrogen in indicating heat concentrations, as in the deutoxide of nitrogen, cyanogen, etc.; while

a few of the nitrides are like the oxides, as the nitride of titanium, in which nitrogen has been got to lose so much of heat as to render it difficult for nitrogen again to regain such a quantity of heat; and hence these nitrides are stable. Some of the nitrides are explosive: an explanation of this, in addition to the one already broached, of the strong heat attraction of nitrogen, particularly when the heat loss has been comparatively small, may be attempted in the following manner:—

In the explosive nitrides, nitrogen is of course allotropic. Now, if we observe the nature of the allotropies of simple bodies, we find that they vary greatly in stability. Thus, the allotropies of carbon are not more remarkable for their great physical differences than for their great permanency or stability, and this it would seem they owe to the great conditional athermism of carbon. It is not so with allotropic red phosphorus, which is apt, on a sudden, and without known cause, to assume, often with explosion, the more common unallotropic form of phosphorus. Again, if the surface of the needle-like crystals of the second variety of allotropic sulphur be merely scratched, these crystals lose at once their allotropy, and pass into common unallotropic sulphur. So that, as we have said, there exists in the allotropies of simple bodies considerable variety in stability, even mechanical causes sufficing, in some

instances, to destroy certain allotropies, such as some of sulphur. It is reasonable to suppose that among the *combination* allotropies of bodies there may be a like variety in stability, and that nitrogen's combination allotropies are of the unstable kind, which they seem to owe to the very great heat attraction of nitrogen.

We shall now proceed to study most briefly the thermics of the gas chlorine, as being in conditional heat the very next to the gas oxygen. But chlorine, though next to oxygen, is athermic when compared with it, for while oxygen is unliquefied, chlorine liquefies easily at four atmospheres' pressure. Chlorine combines with most of the elements, and with some of the metals more readily than oxygen itself, and yet we cannot allow that chlorine has more mechanical attraction for the metals than oxygen has. Chlorine, indeed, must have less than oxygen has, for we have seen or assumed that mechanical attraction depends on the extent of the heat gap or difference between bodies. The wider the heat gap the stronger the mechanical attraction. Now, between chlorine and the metals this heat gap is much less than that between oxygen and the metals, consequently the mechanical attraction between oxygen and the metals must be greater than the mechanical attraction between chlorine and the metals. The undoubted advantage over oxygen that chlorine has in attacking

chemically certain metals depends not on chlorine's superior mechanical attraction, but on chlorine's greater facility of form change, seeing that chlorine, being nearer liquefaction, is nearer form change, for the gas chlorine, because it is comparatively more athermic than oxygen, has not such a downward heat leap to take when chlorine assumes its metallic chloride allotropy, as oxygen has when oxygen passes into the corresponding metallic oxide allotropies ; in other words, free chlorine's form is liker chloride chlorine's form than free oxygen's form is like oxide oxygen's form. Chlorine, therefore, has this very considerable advantage over oxygen, that chlorine's second step in chemical combination with some metals is easier than oxygen's, and chlorine in consequence attacks chemically those metals better than oxygen does. Of the three elements, nitrogen, oxygen, and chlorine, chlorine must have the greatest mechanical attraction for the metal hydrogen, for the heat gap or difference is wider between chlorine and hydrogen than between nitrogen and hydrogen and oxygen and hydrogen ; and as there further exist excellent capabilities in both chlorine and hydrogen for performing the other conditions of chemical combination, and withal the heat contrast of heat conduction and non-conduction, the chemical affinities of chlorine and hydrogen are powerful.

In studying the chemical behaviour of these three

most important metalloids, chlorine, nitrogen, and oxygen, we must bear in mind that between none of the three does there exist the heat conduction and non-conduction contrast, and this greatly influences their chemical acts; for it seems to me quite conceivable that, if in chemical combination one of the combining bodies conducts heat, we should find the heat discharges then taking place more quickly and more completely, we should expect in these cases greater and easier heat losses or heat changes; and this we find to be generally the case, for chlorine loses or discharges much more heat when it combines with an atom of a heat conducting metal such as potassium, etc., than when chlorine unites with an atom of oxygen, a non-conductor of heat, for chloride of potassium is much colder than chloride of oxygen (ClO_2), that is, hypochlorous acid; and not only that, but the metallic chlorides shall be more stable and more changed or transformed than the metalloid chlorides, because chlorine, having lost a good deal of heat in its metallic chlorides, is more altered in form, and cannot so easily regain this heat; and chlorine, having lost but little heat in its metalloid chlorides, chlorine is less altered in form, more easily regains that heat, and with the heat its elementary or free form.

The thermics of phosphorus are of profound interest, from the clear and incontrovertible way that the phosphoric allotropies prove the influence of

conditional and grain heat on the chemical behaviour of substances.

Phosphorus exists in several allotropies, and if we contrast thermally the common or waxy phosphorus with the red amorphous allotropy of phosphorus, we find waxy phosphorus weighs at 50° 1.83, and that it melts at 115° . Red phosphorus, however, weighs 2.14, and melts at 500° . We have, therefore, the red phosphorus less thermic in condition and grain than waxy phosphorus. We have allotropy cooling down for us red phosphorus, as we saw Schrötter cooling down antimony, and, as we might expect, with analogous results; for while conditional and grain hot, waxy phosphorus takes fire, that is, combines chemically with ease when heated but slightly; the conditional and grain-cooled red phosphorus must be heated to 500° before it shows the least chemical activity, or takes fire, or combines with oxygen. And the same thing happens with the allotropies of various substances, as selenium, silicon, etc. etc. So that we have the change in weight and fusion point of a substance—that is, the change of the thermics of the same identical substance—phosphorus completely altering the chemical behaviour of that substance. In what do common and the amorphous phosphorus differ but in weight and in fusion point? But weight and fusion point indicate chemical heat, if our axioms be true. Red and

common phosphorus, therefore, differ in this, that the red is athermic and the common phosphorus is chemically thermic, and, being so, we find the more thermic form of phosphorus the more chemically active of the two.

CHAPTER VI.

WE thus begin to learn how important in chemistry must the *cooling* or athermizing of chemicals be. With the heating of chemicals, chemists are immemorially and abundantly familiar; but to the effects of athermizing, chemists do not seem as yet to be sufficiently alive. But, paradoxical as it may appear, we must yet acknowledge that we do not always make chemicals conditionally more thermic by heating them. You may, on the contrary, make them conditionally less thermic by heating them. What you are almost sure to do by heating chemicals is, to make them change shapes or form; and sometimes your heating will change the chemicals heated into athermic forms, as happens with the metals and oxygen. As happens, indeed, with common phosphorus, which, from moderate but prolonged heating in inactive gases, changes shape, as we have just noted, from a thermic to an athermic form—changes from waxy phosphorus into the red phosphorus.

It is no doubt strange that phosphorus, by being heated for 48 hours moderately, out of contact with

air, should be made to discharge heat—should be made actually chemically less thermic; but this, though strange, is far from being unique in chemistry—far even from being exceptional, but, on the contrary, common.

Thus, you do not make oxygen and hydrogen more thermic by heating them together. You make them less thermic, for you turn these gases into liquid when you heat them. You do not make liquid mercury and gaseous oxygen more thermic by heating them together; you, on the contrary, make them both solid and less thermic than they were before you heated them together.

The modifications produced by athermizing in chemical combinations are very strikingly seen in the influence of that very athermic metal platinum, on very many occasions. I hold that athermic platinum very often influences chemical actions by athermic platinum's great powers of heat attraction, and by its very pronounced cooling or athermizing effects. This athermizing effect of the metal platinum we have already observed in the instance of hydrogen combining with oxygen to form water. Other similar examples abound in chemistry. Thus, two very thermic gases, deutoxide of nitrogen and hydrogen, the former of which liquefies at 50 atmospheres' pressure, and the latter is unliquefied, wish to form the athermic gas ammonia, that liquefies at 6 atmo-

spheres' pressure; and it is clear that these two thermic gases must lose heat in so forming ammonia, and platinum, with its powerful heat attraction, with its strong athermizing effects, helps them as no other reagent can; and in the presence of this athermic platinum, the two aforesaid thermic gases, deutoxide of nitrogen and hydrogen, readily form the less thermic gas ammonia. It is, therefore, when bodies are passing from thermic to athermic forms that athermic platinum can most characteristically favour the chemical action. By the cooling athermizing effects, by the heat attraction of cold platinum, athermic and solid carbonate of ammonia is elaborated from the very thermic gases deutoxide of nitrogen and olefiant gas;—athermic cyanide of ammonium from thermic gaseous hydrogen and cyanogen;—athermic sulphuric acid from gaseous sulphurous acid;—athermic liquefiable carbonic acid from unliquefied carbonic oxide; and so forth. This remarkable property of platinum depends on platinum's being an excessively chemically athermic metal in every respect, and will be consequently shared with platinum by all the athermic metals, according to their pitch of athermism. But as platinum is, among metals, about the most athermic, it must enjoy this heat-attracting property in a pre-eminent way. But it is evident that any substance that will tend to make platinum lose or repel heat, will destroy the heat-attracting

property of platinum under consideration. Now, hydrochloric acid will do this, by causing platinum to wish to become, or to become, a chloride ; that is, to lose or repel heat, instead of attracting it ; and this explains why the presence of hydrochloric acid destroys for the time platinum's heat-attracting powers.

CHAPTER VII.

WE have now pretty often, in the pages of this essay or disquisition, mentioned the third step in chemical combination—namely, the assumption in compounds, by their ingredients, of equal or like heats. And I think it now high time to examine a little more narrowly this most interesting phenomenon. And, first, let us study the successive steps during chemical combinations that lead finally to this heat equilibrium—to this assumption of equal or like heats.

Carbon and sulphur are powdered, mixed, and heated. Now sulphur and carbon have each a different conditional and specific heat, and unequal powers of heat conduction, and the strength of their mechanical attraction depends on this difference in their heats. The carbon and sulphur are heated, and this heating must, for a short time, aggravate their heat dissimilarity, that is, increase the mechanical mutual attraction of carbon and sulphur, so that the ultimate molecules of sulphur and carbon are, by the heating, drawn into the closer juxtaposition, and, being in contact, there is a direct and ready trans-

mission of heat between them, the athermic taking gradually the heat of the thermic; and from the close propinquity of their particles, even any external heat reaching the carbon and sulphur comes eventually to be shared equally by both, to be equally spread over both; and this must gradually modify the heats of both sulphur and carbon, until the two get equally hot or thermic. But to get equally thermic, carbon and sulphur must have altered very much, and thus a new substance is formed—the bisulphide of carbon. For there has resulted from constantly augmented mechanical attraction a thorough mixture of two substances, carbon and sulphur having, because of their mutual heat discharges and absorptions, an equal and new heat, and consequently a new aspect. So that it is a *sine qua non* of chemical union that united ingredients shall have equal or like heats. Whatever difference may have existed in the conditional heats of oxygen and hydrogen before combination, after union, in water, the conditional heats of oxygen and hydrogen are the selfsame. The two elements, oxygen and hydrogen, allotropically mixed up in their compound water, must do and suffer thermally everything in common; they must solidify, melt, vaporise, in common; heat applied to water will affect the two, oxygen and hydrogen, equally and alike. But a very important conclusion flows from this conditional heat equality of ingredients of compounds, and it is simply this—that between

ingredients of chemical compounds there can no longer be any more mechanical attraction ; there must, indeed, be the reverse of mechanical attraction, there must be mechanical REPULSION. For, if we assume that it was INEQUALITY in the heats of oxygen and hydrogen that made them attract to combine, equality in the heats of oxygen and hydrogen, when they have combined, will produce an opposite effect, will make combined oxygen and hydrogen repel each other. So that between oxygen and hydrogen existent, combined in water, there is not the slightest mechanical attraction, nay, there is a mechanical *repulsion*.

We have argued all along that heat inequality produces mechanical attraction in chemistry. Heat equality is the opposite of heat *inequality*, and, therefore, heat equality must produce effects opposite to those of heat inequality, heat equality must produce mechanical repulsion. But what then keeps oxygen and hydrogen from separating in their compound water, since, far from having while in water any mechanical attraction for each other, these two elements have actually a repulsion ?

It is simply this, that to become again disunited or sundered from their unwilling juxtaposition in water—that is, to appear again to us with their old familiar faces—oxygen and hydrogen must get back the enormous heat that these two elements have lost in combining to form water. No easy task !

Fancy the terribly concentrated heat of the oxy-hydrogen blow-pipe, produced by the formation of a few drops of water, by oxygen and hydrogen ; where in nature shall the oxygen and hydrogen of these few drops of water thus formed readily find again this great heat that they lost, but which they must regain, in order to re-acquire their pristine gaseous forms ? For it is evident that the heat that was lost by water's ingredients must again be restored to these ingredients before they can cast off their water allotropies, and appear in their gaseous, elementary, naked shapes. The great difficulty of obtaining this immense heat is one of the chief reasons why water is a very stable compound. And the proof of this is, that let this concentrated heat, and nothing but this heat, be again given to hydrogen and oxygen of water, by plunging into water a piece of platinum, incandescent by the current of a galvanic battery, or melted by the oxy-hydrogen blow-pipe, and the mutual repulsion of that water's components, oxygen and hydrogen, is at once apparent, for they quickly separate, and take their gaseous forms, and water is, as it is termed, decomposed by the unaided heat of incandescent platinum.

We hold that combined oxygen and hydrogen, in the allotropy of equal or like heats in which the two exist in water, repel each other ; but what is the cause of their repulsion ? It is their equal or

like heats. Intensify this heat by heating greatly combined hydrogen and oxygen, and you must thereby intensify the repulsion between combined hydrogen and oxygen until the repulsion becomes separation. So that this intense heat in the platinum, incandescent by a battery, has two effects, when it decomposes water: this heat in the platinum increases first the already existing repulsion in water's ingredients, oxygen and hydrogen; and, secondly, the same heat transforms these same ingredients from the thermic liquid form to the thermic gaseous shape.

Again, let us take mercury, and heat it up to a certain pitch, and mercury's conditional heat reaches its discharging point—that is, mercury loses heat, and attracts and combines with oxygen, and then both oxygen and mercury assume their combination, solid form, and equal or like heats, and therefore repel each other.

What, then, keeps mercury from separating from oxygen, while it exists in mercurial oxide?

It is a similar cause that kept unwilling oxygen and hydrogen together in their compound water. It is, that to become disunited combined mercury and oxygen must obtain again the heat that the two have lost in combining. And as this heat is much less than that in the case of oxygen and hydrogen, it is easier to do. Give mercury and oxygen of the oxide this heat, continue to heat the mercurial oxide strongly,

and you again, by means of the increased heat, separate the oxygen and mercury, making them resume their usual elementary terrestrial aspects.

The loss, the gain, the transference, the equilibrium of conditional heat, seem most satisfactorily to explain all these complex and seemingly highly contradictory phenomena.

Reasoning from these two instructive cases, we must conclude that every metallic oxide is reducible by heat alone, and unaided, provided of course the heat be strong enough. The metallic oxides more difficult of reduction, those of the chemically thermic metals, such as potassa, soda, etc., requiring, as we shall find, for this purpose the fierce and greatly concentrated heat of the voltaic battery. For of course the more thermic a metal is the more heat it will require for its reduction, and the less it is in the nature of such metals to attract heat: their nature, as we have seen, leading them to discharge or repel heat far more than to attract it; hence the difficulty of their deoxidation or reduction. But we must farther recollect that the difficulty of the reduction of metallic oxides by unaided heat is greatly enhanced by the fact that the metals, in their oxide allotropies, no longer conduct heat.

But the very thermic metals—that is, those difficult of reduction—are seldom in practice reduced by heat alone, for it is easier, and vastly more convenient, to

duce them while assisting the ever-indispensable heat by other reactions. Thus sometimes the help of hydrogen is chosen for this purpose. When hydrogen assists in decomposing the oxide of iron at high temperatures, we may perceive the following phenomena :

—The iron and its oxygen, as they exist in oxide of iron, have the heat of equilibrium, have like heats, and therefore the iron and the oxygen in the oxide of iron are repelling each other. This oxide of iron is heated in the presence of hydrogen ; we have thus in action four substances — namely, oxygen, iron, hydrogen, and the heat in which the three chemicals are bathed or heated. Of these four substances the iron repels its partner oxygen, for these two are in combination, and have thus like heats ; hydrogen, however, attracts the oxygen, for the free hydrogen has unequal heat to that of oxygen ; and, finally, the heat in which the oxygen, iron, and hydrogen are heated, has the effect, as we have seen, of intensifying or making greater the repulsion of the iron for its partner oxygen, and the attraction of hydrogen for the same oxygen. It follows, then, that in this case iron will separate from oxygen, for the iron is driving away the oxygen, and hydrogen is also dragging the oxygen away from the iron, so that the oxygen yields to these two forces of iron repulsion and hydrogen attraction, and passes to the hydrogen attracting it. *Per saltum*, therefore, hydrogen loses conditional

heat and takes the oxygen of the iron oxide, the iron of which simultaneously attracts the lost heat of the hydrogen, and by absorption of this heat the iron undergoes the metallic transformation—that is, becomes reduced or free. Hydrogen and iron exchange places. The hydrogen frees the iron from its repellant captivity, and goes into thralldom itself in iron's stead. But strange, and yet necessarily, the iron, the very moment it gets freed, actually longs again for its old bonds, and is quite ready, if you give it the means you gave to hydrogen, to free the now imprisoned and oxygen-repelling hydrogen, precisely as the iron itself was freed. For free iron, at a red heat, easily takes the oxygen from the hydrogen combined with it in the vapour of water: for it is clear that in the last case the attraction is reversed, and it is now the free iron that attracts the oxygen, and the combined hydrogen that repels its partner the oxygen of water—the oxygen attraction is now with the free iron, the oxygen repulsion is with the hydrogen united to that oxygen in water.

So that, when hydrogen reduced the iron of the oxide of iron at high temperature, it is not because hydrogen has a greater unvarying attraction or affinity for oxygen than iron has, but the attraction that exists in these circumstances between hydrogen and oxygen is quite a mechanical attraction, caused by inequality of conditional heat, which attraction

hydrogen, and indeed all chemicals, lose by the loss of that heat inequality, and which selfsame attraction iron at once gains, when iron, or indeed any chemical, acquires the heat inequality. And this leads us naturally to ask in what then consists true chemical affinity?

CHAPTER VIII.

NATURE seems to me to have divided the chemical elements into three great classes, and to have bestowed on each of these classes its own peculiar chemical properties.

The first class includes—

The elements that have great chemical might, or power, or craft, or, better still, shapecraft—such as oxygen, hydrogen, carbon, nitrogen.

The second great class includes—

The elements that have great chemical activity—as potassium, sodium, etc.

The third great class includes—

The elements that are truly negative—that is, that have neither shapecraft nor activity—such as platinum, gold, etc. etc.

So that I rank oxygen, hydrogen, and carbon, wedded to heat, as the first and noblest kind of matter in the domains of chemistry, as the very greatest of chemical substances, as having the most chemical might or shapecraft, the true crowned

heads of chemistry. In carbon and oxygen, in carbon and hydrogen, there exists complete aptitudes for perfectly and easily performing the three indispensable requisites of chemical combinations. The heat-gap between them is the widest that exists, and therefore their mechanical attraction, that important step in all chemical combination, is the strongest in chemistry. The heat latent in the recondite ultimate recesses and molecules of each and all of them, is such, that to them *Morphigenesis* is child's play. And, consequently, their simple and combination allotropies, or glowshapes, range from the greatest of terrestrial cold in the diamond and in yttria, to the greatest of heat in free hydrogen. Ascent and descent of the whole extent of the terrestrial heat scale is alike easy to them. Hence the miraculous infinitude of their compounds in organic and inorganic chemistry. So that, were a definition of the most perfect true chemical affinity asked, the answer would be, that it was that which exists between carbon and oxygen and carbon and hydrogen; and finally, that which exists between the whole three—carbon, oxygen, and hydrogen.

For carbon, I repeat, is conditionally by far the most athermic of the elements, and oxygen is all but the most thermic; hence oxygen and carbon have intensely opposite states of heat, which makes the mechanical attraction between

carbon and oxygen of the strongest and most perfect kind. Further, the allotropies of oxygen and carbon are well matched, for both these elements show kaleidoscopic plasticity in the creative hands of heat, an illimitably great shapecraft. For oxygen appears in this planet in every shade of combination allotropy, starting from the very thermic shape of unliquefied gas, as in deutoxide of nitrogen, and reaching to an utterly infusible athermic solid state in the oxide of calcium or lime. And between these very thermic and very athermic shapes, oxygen occurs in almost every conceivable state of heat. To oxygen is the ascent or the descent to and from the very opposite extremes of the heat scale alike easy.

Carbon's allotropies, or heat-shapes or glow-shapes, also start from the lowest state of terrestrial cold, in the utterly infusible and insoluble diamond, and attain the very thermic degree of unliquefied gas in carbonic oxide; and between these very thermic and athermic states carbon is also found in every imaginable heat-shape. So that ascent and descent of the heat-scale is equally easy to carbon. So that attraction, heat transformations, and heat equilibrium between carbon and oxygen exist in the utmost excellence, and these two have the most consummate chemical aptitudes and true affinities. No other substance has such an *extreme* range of allotropies as carbon and oxygen have. Hydrogen comes next, but hydrogen

is a heat-conducting metallic substance, so extremely thermic in every respect—by condition, by weight, and specific heat—that hydrogen never seems able to assume utter athermism and utter infusibility, as carbon and oxygen do. But this by no means unfits hydrogen for the part it has to play in organic chemistry, for great athermism is unnecessary in hydrogen's organic allotropies—nay, great athermism might be incompatible with organised life ; and it may be suggestive to note that there exists, forming part of highly complex compounds of living beings, at least one element—hydrogen—that is not only the most thermic known, but that is also loath to part with its entire heat—whose heat, or whose heat-life, it is very difficult to extinguish. But between utterly infusible carbon, conditionally the most athermic of the elements, and the utterly unliquefied gas, hydrogen, the most thermic of known bodies, there must exist the widest of heat-gaps, the greatest of heat-difference, and, if our speculations be true, the very strongest of mechanical attraction in chemistry. As to the other heat properties of hydrogen and carbon, they harmonise so well that the allotropies of carbon and hydrogen easily dovetail into each other and equilibrate. So that the true chemical affinities of carbon and hydrogen, within a certain but extensive heat-range, are far greater than even those of oxygen and carbon.

But when these three chemicals—oxygen, hydrogen, and carbon—unite their powers, there results the wonders of the compounds of the vegetable world.

I call potassium chemically active, because potassium's chemical acts are violent and energetic, so much so that potassium cannot exist, even for a moment, in air, without entering into chemical action. But to what does it all amount? Certainly not much. For although potassium and the thermic metals are impetuous in their chemical behaviour, still they have but little shapecraft, for the compounds that they are able to make are comparatively few and simple, as appears when you contrast the number of the compounds of potassium with those of the carbon, for then potassium's meagre list makes a sorry figure side by side with the numberless variety of the organic compounds in which carbon essentially enters.

In fine, potassium's chemical combinations are startling from their vigour and impetuosity, and carbon's miraculous in their infinitude. In still shorter terms, potassium has great chemical activity, but carbon has what I shall call great chemical shapecraft.

Platinum, iridium, gold, silver, and the other noble metals, are notable in general for the difficulty of their passing into combination and facility in passing out of combination.

Chemical shapecraft depends upon fully developed chemical powers, and must include capabilities for complying with or overcoming all the intricacies of chemical unions, and infers considerable atomic and grain heats, and, besides, a nicely adjusted balance in all the three heat properties, and often the co-operative intervention of vital force.

Chemical activity may result from much simpler heat adjustments, may be conferred by mere great conditional heat, if not unduly counterbalanced by great grain and atomic coldness. Chemical activity depends on the active substance being ever ready to change form, or prone to take the second step in chemical combinations ; hence such elements are not easily found uncombined. For great conditional heat shows in its possessors a proximity to form change, while great atomic and grain heat show great capabilities for form change ; hence what will it avail a chemical, such as mercury, its great conditional heat and its consequent proximity to form change, if mercury's grain and atomic heats indicate inaptitude in mercury for form change ? However near mercury may be to form change, it must change but badly if it be almost incapable of form changing. It is as if mercury had not far to go, but could not walk.

Carbon's great conditional athermism shows carbon's great distance from form change, but carbon's

great atomic and grain heat show in carbon great aptitude for form change, so that carbon changes form in spite of its distance from form change. It is as if carbon had very far to go, but had likewise great strength, wind, and speed.

The chemical incompetency of negative metals is impressed on them by their athermism; by the absence, often almost complete, in their textures, of the Enchanter—Heat.

From these remarks it becomes evident that of all the three steps necessary for chemical combinations, that of attraction, is, on the whole, the least important. For many chemicals, such as, for example, the noble metals, attract well and combine badly. For attraction in chemistry is in fact mechanical attraction, precisely the same as the attractions elsewhere met with, and can thus only cause close juxtaposition of the atoms of attracting chemicals, and no more: and but brings those atoms thus within easy heat-striking distance—that is, brings those atoms under the influence of close heat discharges, and facilitates those discharges.

Attraction in chemistry but produces molecular approximations; doubtless a most important effect. But not all the attraction in chemistry, nor in the universe, can be conceived to elaborate form change, the sole prerogative of morphigenic heat, the act of the heat of chemical transformation alone.

To conclude, we find that the patient scrutiny and careful analysis of chemical action has led to the establishment of some simple ideas, or, as I would fain say, formulæ or laws—namely, that chemical action—that is, combination and decomposition—consists of mechanical attraction, mechanical repulsion, inequality, discharge, equilibrium of heat.

Difference or inequality of heat producing mechanical attraction ; equilibrium, or equality, or similarity of heat causing mechanical repulsion ; discharges of heat causing form change or transformation.

Mechanical attraction existing more or less universally among free chemicals.

Mechanical repulsion existing only among the ingredients mixed up in compounds.

Morphigenic heat discharges being present during every chemical action.

CHAPTER IX.

WE have thus, during the course of this essay, observed that the conditional heat, or morphigenic heat, or *si licet Morphigen*, of each element, was different from that of the other; but that, if we grouped those chemical elements, they might be divided into two sets, a thermic and an athermic set, metals and metalloids, and that these thermic and athermic sets mechanically attracted each other, and combined; and that the first series of compounds of these groups of simple elementary bodies, the acids and bases, also preserved this character of thermic and athermic, and consequently of mutual mechanical attraction and chemical affinities and activity,—the acids springing mostly from the thermic group of the elements, and preserving a good deal of the heat of their race intact,—the little of the thermic metalloid element that exists in a base undergoing thermal degeneration, losing its congenital heat in the very act of becoming basic,—in assuming its basic allotropy or glowshape.

If we pursue, as we are now bound to do, the investigation of the second series of chemical com-

binations, that, namely, occurring between acids and bases, we find that this opposite character of thermic and athermic disappears in the compounds of acids and bases, that is, in salts; and, with the loss of these heat properties, most of the chemical activity in salts, that is the power of forming fresh compounds, is lost also.

What thermo-chemical phenomena occur during the combination of such athermic bases with such thermic acids?

When gaseous carbonic acid unites with the oxide of sodium base, soda,—a solid compound,—results; the carbonate of soda and the acid is neutralised. Gaseous carbonic acid must have, according to our axioms, lost heat, burnt, discharged heat, in such a combination as the above, for carbonic acid has there passed from gaseity to solidity, from thermism to athermism, and in losing this heat in burning, carbonic acid lost its acidity also.

Again, if hydrochloric acid, which is also gaseous, be added to the base, oxide of sodium, or soda, a solid compound, is made—common table salt, chloride of sodium, and the hydrochloric acid's acidity disappears. Gaseous chlorine, as existing in hydrochloric acid, in becoming solid in the table salt, has passed from thermism to athermism, must have lost morphigen, or conditional heat, and so must have burnt.

In losing, therefore, its acidity, hydrochloric acid has to lose or to discharge heat, or has to be burnt.

Again, if hydrochloric acid be added to the carbonate of soda, we have that carbonate of soda decomposed, and its carbonic acid set free as a gas of considerable rarity. But in the carbonate of soda, carbonic acid existed as a fixed solid and neutral substance, and to have passed from solidity to gaseity, from neutrality to acidity, the carbonic acid must have gained or absorbed heat: and this heat the carbonic acid obtains from the hydrochloric acid's saline transformation or combustion, as hydrochloric acid is combining with the sodium of the carbonate of soda, or burning, and thereby passing from gaseity to solidity, from acidity to neutrality.

Now, as most of the acids will readily displace the carbonic, and, while so displacing it, will evolve it as gas, it follows that most acids lose, repel, discharge heat, burn, when they become neutralised, and regain this lost heat when they reassume the acid shape, or glow-shape.

So that we must conclude, that just as there was a latent heat of metallicity lost and gained in the oxidation and reduction of metals, so there exists also a latent heat of acidity, lost and gained in the neutralisation and recombination of acids, in the combustion and reduction of acids. But the combination of acids and bases, the acido-basic combustion, unlike

the oxy-metallic combustion, is seldom or never characterised by the appearance of flame, or of even heat, for there does not exist in acids and bases so much inherent heat as in oxygen and the metals. For a base we know to be cold, the base's ingredients having suffered complete thermal degeneration in forming the base, and even the heat present in the acid being less concentrated than the heat of oxygen, inasmuch as that heat is spread over more substances than one. Moreover, neither acid nor base conducts heat, and their combustion always takes place in solutions or liquids, it therefore follows that the acido-basic combustions cannot produce the violent and striking heat phenomena of the oxy-metallic burnings.

We now pass on to scrutinise more closely the thermal phenomena occurring when a solution of an acid is added to a solution of any salt.

In these complex reactions of bodies there must often occur chemical composition, side by side with chemical decomposition, and both these two must, therefore, be again thoroughly analysed before such reactions can be at all comprehended.

It must, therefore, be here again repeated that chemical combinations consist of mechanical attraction, morphigenic heat changes, and finally heat equality. While chemical decomposition consists of *repulsion*, morphigenic heat changes, and heat inequality.

How can chemical bodies unite if they do not

attract? How can chemical bodies disunite or separate if they did not repel each other?

Composition is quite analogous to decomposition, but in an inverse sense. In composition there is union, but in decomposition there is a separation.

In composition, it has long been admitted, there is an attraction; in decomposition it seems perfectly in reason to hold that the reverse of what takes place in composition should occur—namely, repulsion.

In chemical union there is always an attraction, but this attraction is merely mechanical, and by itself or singly, suffices not for chemical union. There must be further the all-important morphigenic heat changes. For, as we have already said, the greatest mechanical attraction in the universe cannot singly cause chemical action or union.

It is perfectly analogous with all chemical decomposition; in decomposition there must exist mechanical repulsion, but this singly suffices not; the very strongest mechanical repulsion that exists cannot singly effect chemical decomposition, there must be present also the absolutely necessary morphigenic heat changes.

Having thus broken ground, we go on to observe what takes place when a solution of any acid is added to that of any salt.

First, the added acid may displace the acid of the

salt, provided that the added or displacing acid, in undergoing the saline allotropy it must in burning, in order to take the place of the acid of the salt, then discharge heat sufficient for the production of the corresponding acid allotropy that the displaced acid of the salt has to take. In other words, the added free acid may displace the combined acid of the salt, if the added free acid, in its salification with the base of the salt, or in its combustion, discharge the necessary heat for the *unsalification* of the combined acid of the salt, for the acidifying of the combined and therefore allotropically saline acid of the salt.

For we know that the acid of the salt and the base of the salt being in union, have like heats, and hence mutual repulsion. The acid of the salt repels its partner, the base of the salt. But the added acid is free, and thus attracts the base of the salt, the two having unequal heats; and therefore, if the added free acid can at all fulfil the other conditions of chemical decomposition—that is, if the added acid can by its salification or combustion yield sufficient heat—it will, by virtue of its attraction for the base, free, that is acidify, the acid of the salt, and get into that acid's place.

If the displacing acid form with the base of the displaced acid an insoluble salt, the chemical action will consist quite simply of an exchange of acids by the base, and the action will end with the production of the new and insoluble salt, which, from its insolubility, is thrown out of the field of action *hors du combat*.

The action will be also simple and definite when the displaced acid is gaseous, as carbonic acid, for the displaced acid then evacuates the field, leaving it entirely to the acid's displacer.

But matters become very curiously complicated when the salt formed by the displacing acid is as soluble as the first salt, that is, the salt of the displaced acid ; for in that case the displaced acid, the moment it is displaced, tends to displace again its displacer, for, of course, then the attraction of the two acids is reversed ; the displacing acid will, after combination with it, repel the base, and the now free displaced acid will attract the base, and the keeping of the base by the acids will depend upon the amount of heat that each acid loses in combining with that particular base, or in burning. If this heat be equal, then the composition of the mixture will be constantly varying, there will be a constant exchange of acids by the base.

If the amount of heat lost by the two acids be slightly different, then probably the acid that loses most heat in its salification or combustion will take and keep most base, and the other acid may have a smaller quantity. But if the added acid lose much more heat than the acid of the salt, then the added acid will take all the base and keep it.

But the added acid may not have the power, by its saline transformations, to yield heat sufficient for the acidifying transformation of the allotropically

saline acid of the salt, and then, of course, no decomposition of the salt will occur; and such an added acid is thought and termed a weak one.

Thus if a hot and not too concentrated solution of the borate of soda (borax) be mixed with sulphuric acid, the sulphuric acid attracts the soda away from the boracic acid completely, and the boracic acid remains in solution (as is known by its very peculiar action on litmus paper), together with the newly-formed sulphate of soda. Nor does the boracic make any attempt to get back its soda again. It cannot. For any chemical salification or combination that boracic acid can undergo (in solution) with soda does not yield enough of heat to acidify the now allotropically saline sulphuric acid of the sulphate of soda. Boracic acid, while in solution, cannot fulfil, with respect to the sulphate of soda, all the conditions of chemical decomposition. Boracic acid free certainly will attract the soda in the sulphate of soda, but cannot give heat by the acid's own combination or salification for the acidifying of the sulphuric acid of the sulphate of soda; boracic acid therefore cannot decompose the sulphate of soda, but this is said to happen because the sulphuric acid has a stronger attraction for soda than the boracic acid. But it is not so.

By the new theory sulphuric acid and soda have no mechanical attraction for each other, in the sulphate of soda they have a repulsion. Consequently, any

attraction, even the smallest, that boracic acid may have for the said soda, will give boracic acid an advantage in getting possession of the soda over sulphuric acid of the sulphate of soda, if that sulphuric acid is repelling the said soda. That the sulphuric acid has no real greater attraction for soda, when soda is its partner, in sulphate of soda, than free boracic acid has, is proved by heating the free boracic acid with the sulphate of soda, and then boracic acid, that so-called feeblest of acids, readily displaces that so-called strongest of acids—the sulphuric of the sulphate of soda!—the sulphate of soda becomes the borate of soda, for under these circumstances the boracic acid can fulfil all the conditions of chemical decomposition. For the free boracic acid attracts the soda that its sulphuric acid is repelling, and the heat of chemical transformations is furnished artificially. So that, under certain heat circumstances, we have the acknowledged feeble affinity of the feeblest of acids, boracic acid, easily overcoming the so-called strong affinity of the strongest of acids, the sulphuric—heat, and heat unassisted, having given such telling help to the weak that the weak overmastered the strong. But in fact there was no affinity or strength to overcome. The difficulty to conquer was the furnishing of heat for the chemical transformations, or the acidifying of the sulphuric acid from its saline combined allotropic state into its free and acid state—an

entirely heat difficulty, and thus to be solved by heat alone. I repeat that these are entirely heat phenomena, and not in the least dependent on affinity or attraction between ingredients or partners in compounds.

It seems indeed strange that it does not forcibly occur to the mind that as when an acid and a base combine each loses completely all its distinctive characters, so the acid and base must lose also their attraction for each other after their combination.

Everything in the acid and base is changed by their combination,—is as it were reversed ; it seems natural to think that their mutual attraction has also changed, or been reversed into repulsion.

It sometimes happens that a weak acid is placed in such favourable heat circumstances as to enable that weak acid to displace a very strong acid, even without the assistance of the slightest extraneous heat.

Thus weak tartaric acid will free or displace strong sulphuric acid in a solution of the sulphate of silver. This supposed weak tartaric acid will take per force the oxide of silver base from the supposed very strong sulphuric acid—that is, will decompose the sulphate of silver solution. And this simply because the tartrate of silver, the result of such a decomposition, is insoluble. And this insolubility brings it about that in this particular case not only does the tartaric acid's salification or combustion afford heat,

but also the passage of the oxide of silver from the sulphuric acid to the tartaric acid affords also heat, for this oxide of silver passes then from solubility into insolubility, from thermism to athermism, and therefore loses heat. So that in this case we have a double discharge of heat—one discharge from the changing oxide of silver, and the other from the salifying, burning, tartaric acid. And this double amount of heat thus discharged, proves in this case, but not necessarily in every case, sufficient to acidify the allotropically saline sulphuric acid; and thus the very weak tartaric acid comes to overmaster the supposed very strong sulphuric acid.

So that each acid, in becoming saline or salified, seems to burn, to lose its own peculiar amount of heat, different from that of every one of its *confrères*, and the acid that salifies or burns with the discharge of most heat is held the strongest, for that acid will, under common circumstances, displace all the other acids, and will be itself, from the great quantity of heat required, undisplaceable by other unaided acids. But no acid is really inherently strong; it is alone through its heat properties that an acid gets its strength of affinity and attraction. Lend these heat qualities to the feeblest of acids that exists, and we have just seen that the feeble acid will master the strongest: deprive the strongest of acids of these heat properties, and it becomes weak.

That acids lose each a different amount of heat in assuming their saline heat shape—that is, in salifying or combining with bases or burning—is the reason that two salts of different acids decompose each other, that a solution of acetate of lead will decompose, for example, one of sulphate of alumina. For the allotropically saline acetic acid, and the saline sulphuric acid, are in a different state of heat, and each will thus attract the base of the other, while each of course will repel its own partner base. In recapitulation, we may say that any acid will replace another in a salt, provided the replacer's salification or combustion will yield heat enough for the replaced's acidifying. Any acid will displace another in a salt, even when the displacer's salification or combustion does not yield the sufficient heat for the acidifying of the displaced acid, if this deficiency in the heat be made up by extraneous means or concurrent chemical action. No acid will displace another in a salt as long as the would-be displacer acid cannot yield by its salification or combustion, or obtain by other means, sufficient heat for the acidifying of the acid that ought to be displaced.

Hence any fixed acid, however weak, that can bear a sufficient heat without its own decomposition, will displace every volatile acid.

It is clear that the reasoning that applies to the acids will, *mutatis mutandis*, apply also to the bases.

CHAPTER X.

WE are now fully prepared to understand why zinc or iron does not, singly and alone, decompose water. And as this phenomenon has a remote bearing on the galvanic battery, which we are about to study, we cannot but enter into its discussion and attempt its explanation. Water is an oxide of hydrogen—a metallic oxide; a metal, therefore, decomposing water must combine with water's oxygen, and reduce the water's hydrogen. But to evolve water's allotropically liquid hydrogen as gas, to boil water's liquid hydrogen requires great heat, and therefore good fuel to give this heat. But good fuel means a substance having great heat in little bulk—that is, if our axioms be true, a metal near its fusion point, very light, with strong specific heat. Therefore all the metals that can decompose water singly and unaided, as sodium, potassium, etc., are good fuel—that is, excel in one or more, or all, of the aforesaid heat properties, of lightness, great fusibility, great specific heat. Zinc or iron, being much less thermic than the above class of metals, potassium, etc., is not so good fuel; and,

therefore, when zinc has to decompose water—that is, to boil liquid hydrogen—some other fuel must be burnt with zinc, so as to make the heat produced suffice for the vaporisation of the hydrogen. To the heat, therefore, of the zinc combustion we add the heat of an acid's (the sulphuric) salification, which salification, we have just seen, discharges heat, and is therefore a veritable combustion. And the burning of this double quantity of fuel, the zinc and the acid, gives heat that suffices to boil the liquid hydrogen to gas or steam—that is, to decompose water. The zinc, as it becomes an oxide, or as it burns, the sulphuric acid, as it becomes a sulphate, or as it salifies or burns, both discharge heat, and therefore there is enough of heat for the boiling of the liquid hydrogen. And thus water can be decomposed by united zinc and sulphuric acid, though the water cannot be decomposed by zinc alone.

With iron the proceeding may be more easily understood, for the simple heating of the iron suffices to enable it to boil the liquid hydrogen—the difficulty in the decomposition of water ; for in this case there is the heat art gave to the iron, and, further, the heat of the iron's own oxidation or combustion, and these two heats suffice when one was not enough.

So that, if these views be correct, the best fuel in the world ought to be hydrogen, for hydrogen has the very smallest of atomic weight, the greatest lightness

and the highest conditional heat and heat conduction; and that such is the case, that hydrogen is the best of fuels, the oxy-hydrogen blow-pipe amply shows forth.

PART II.

GALVANIC BATTERY.

ELECTROTHERMOLOGY OF CHEMISTRY.

CHAPTER I.

WE have thus, somewhat imperfectly, discussed Heat in chemistry, Thermochemics—first noting heat's existence, then the changes heat underwent, and also the alterations the heat itself brought about. We found that certain modifications in heat produced transformations, those marvels of chemistry. Other modifications of heat caused chemical activity; and others, again, inactivity; others, chemical shapecraft; and that even attraction and repulsion in chemistry were mechanical, and attributable to heat causes.

It is incumbent on us now to pass to the consideration of other still more remarkable properties of this conditional or morphigenic heat, as seen in the galvanic battery.

Taking a common old-fashioned form of the galvanic battery for study, we find that the chemical phenomena going on in any one of its cells are the

same as those going on in all the other cells. So that to study these phenomena one cell amply suffices. Such a galvanic cell is best composed of zinc and platinum plates immersed in an oxidising fluid—generally water acidulated with sulphuric acid, etc.—the platinum and zinc plates being connected by a wire attached to their edges above the fluid or water of the cell.

In such a galvanic cell what are the phenomena going on?

The essential phenomenon in the galvanic cell, as admitted by all, is the oxidation of the zinc plate, because *to this oxidation the best electricians trace the ultimate development of voltaic electricity*. Let us restrict ourselves, therefore, to this zinc oxidation, neglecting for the present the influence of the platinum plate on such an oxidation—taking away the platinum plate altogether from the galvanic cell under our investigation.

Well, then, the acknowledged essential phenomenon of the galvanic battery is the oxidation of a metal—zinc. But oxidation is synonymous with burning. Zinc, oxidising rapidly in air, we have most carefully proved, burns, loses, repels, discharges its heat of metallicity to assume zinc's oxide heat shape. No one has a doubt that zinc's rapid oxidation in air is *burning*—heat discharging; and the cause of this heat discharge is a change of shape by the *metal*

zinc into *oxide* zinc—into ash zinc. Whenever, therefore, there is this heat discharge by zinc, there will result a change of shape in the *metal* zinc into *oxide* zinc—into ash zinc; and whenever there is this change of shape by the *metal* zinc into *oxide* zinc, there will be the heat discharge; whenever we see the ashes of zinc, we know that zinc has burnt. But when zinc decomposes water in the galvanic cell, zinc oxidises at the expense of the oxygen of the water, and, of course, there will then be this change of metallic zinc into oxide—into ash zinc—the metal zinc is reduced to ashes, and consequently there must be the corresponding heat loss. What becomes of this heat thus lost by the burning zinc in the cell of the battery? When we look at the surface of the plate of zinc that is decomposing water—that is oxidising or burning in the galvanic cell from which we had taken away the platinum plate—we see that that zinc is in truth burning. We see heat on it. We find the burning zinc's surface covered by boiling hydrogen—that is, covered by bubbles of a gas of extreme tenuity—hydrogen, which gas existed previously as a liquid, as one of the water's ingredients; for hydrogen must exist, while an ingredient of water, in a state of liquidity, in a liquid Allotropy; and this allotropic liquid hydrogen boils, or is evolved as gas from the surface of a metal—zinc, which we know is in the act of being

reduced to ashes in the act of oxide shape change, or of burning.

We have thus in this galvanic cell the zinc plate burning, discharging heat and hydrogen liquid by its water allotropy, taking this heat of the zinc combustion for liquid hydrogen's own evolution as gas.

The burning of the zinc, and the boiling or vaporisation of the liquid hydrogen from that burning zinc's surface, go on *pari passu*. For every 65 grains of zinc that are burnt, 1 grain of hydrogen is evolved; for such is the capacity for heat of the two metals, zinc and hydrogen. There is a loss of heat by the zinc, which may therefore be called *minus* or negative as to heat; and there is an addition of this very heat to the hydrogen, which may therefore be called *plus* or positive as to this heat, with the fluid of the cell the hydrogen is pervading. Nor can there be any very *glaring* appearance of heat of the common kind during these heat-fraught chemical actions, for the heat in question passes from being latent in the one metal, zinc, to being at once latent in the other metal, hydrogen—the heat's development and discharge by the zinc, and the same heat's absorption by the hydrogen, being quite synchronous and equal. The principle here evoked and put in motion must be *heat*—the latent heat of metallicity, morphigenic heat, the heat of chemical transformation—for it originates in a burning of shape changing metal, zinc, and the prin-

ciple raises or transforms liquid allotropic hydrogen into a gas, the principle being given and received only in the proportion of the capacities for *heat* of the two metals, zinc and hydrogen, giving and receiving it.

In familiar homely words, it might be said that this principle is heat, because the metal, in order to yield it, is reduced to ashes, and the liquid that receives it is reduced to steam or gas—is boiled.

Let us now restore again the platinum plate taken away, to the voltaic cell under inspection, and connect the restored platinum by a wire with the zinc plate. The effects we then occasion, the effects of the presence of the platinum plate and its connection with the zinc by wire, in the galvanic cell, are two,—

1st, The presence there, and the metallic contact of platinum with zinc, increases zinc's oxidation, or determines it if not present from weakness of the oxidising fluid, etc.

2d, The place of the boiling or evolution of hydrogen changes from the zinc to the platinum plate, that is, that which boils or vaporises hydrogen, heat, has been attracted from the zinc, where it is developed, to the platinum, from which it then passes to the hydrogen.

For in the completed galvanic cell which we now study, we have to do with three metals, hydrogen, platinum, zinc; of these three metals, hydrogen is, according to our axioms, by far the most thermic;

nay, hydrogen is chemically by far the most thermic metal known,—the hottest matter in the world, it is therefore hydrogen's nature to *repel* heat and not to attract it, to give heat but not to receive it, for hydrogen has too much heat already. Platinum, another metal in the galvanic cell, is by our axioms one of chemically the most athermic of metals, and therefore platinum's heat nature is the very reverse of hydrogen's; platinum's athermism causing it to attract heat and not to repel it, to receive heat and not to give it, for cold platinum has little heat to give away, and much room for heat.

In connection with these two metals, hydrogen and platinum, the first the very worst, and the second the very best, receiver or attractor of heat, we have in our galvanic cell another metal, zinc, that is discharging or giving heat, and between the heat-giving zinc and the heat-attractor platinum, we put a wire, a good heat passage; the zinc's heat then, as is natural, passes or is discharged first to the platinum that attracted it and gave it hearty welcome, through the wire passage of easy heat transit, in preference to the heats being discharged directly into the comparatively heat-repeller hydrogen. In other words, zinc in the galvanic battery, discharging heat and having the choice between the capital heat-receiver platinum and the bad heat-receiver hydrogen, prefers of course the good, and zinc thus discharges its heat

first into platinum ; it is easier so to do. Or in still other terms, heat in the cell of the galvanic battery being repelled from the zinc, has two metals to whom it must go, and the heat prefers that metal, the athermic platinum, that best attracts and receives the heat.

It is clear that you must facilitate heat discharges from the zinc plate of the cell in the battery ; if you present to that zinc plate instead of the bad heat-receiver hydrogen, a very good heat-receiver, nay attractor, such as platinum, and by facilitating zinc's heat discharges you must at the same time facilitate zinc's oxidation, which we have again and again seen, by our axioms, consists of heat discharge, and this is the reason why the addition of the platinum plate to the cell, and its connection by wire with the zinc, leads always to an increase of the chemical action on the zinc.

And as it is platinum's athermic nature and consequent heat attraction that makes it a good heat-receiver, and thus fits platinum for that particular place of the galvanic battery, so all the metals that are athermic, or more athermic than zinc, will have the like powers, more or less, according to amount of their conditional athermism. And also carbon ; for we have found that carbon conducts heat and is conditionally the most athermic of the elements.

The presence, therefore, of the athermic platinum, and indeed of all metals of the athermic class,

in the cell of the galvanic battery, serves to facilitate the discharge of the heat of chemical transformation from the zinc plate, by which zinc is enabled to oxidise faster and better, and serves also the more important purpose of attracting this heat so strongly as to cause the heat to take an unusual roundabout course, by a wire, on which we can at will study many a strange property in this heat. It is therefore highly important that this heat attraction of the platinum plate of the cell of the galvanic battery should take place in the strongest manner; and this is simply obtained by making the platinum plate very large. Of course it is also highly requisite that the zinc plate in the cell of the galvanic battery should give, yield, or discharge, as much of this precious heat as possible. Now, we know that the more thermic a metal is conditionally, the more heat it will be inclined to discharge; and we also know by our axioms that the nearer a metal is to its fusion point, the more thermic conditionally it is; so that if we could by any means lower zinc's fusion point, we would make zinc conditionally more thermic, and thus a better heat-yielder or discharger; and this has been for long empirically done by amalgamating slightly the zinc plate with that very conditionally thermic metal, mercury; for by alloying metals we generally lower their fusion-points without destroying their metallicity.

There is therefore in the single voltaic cell under

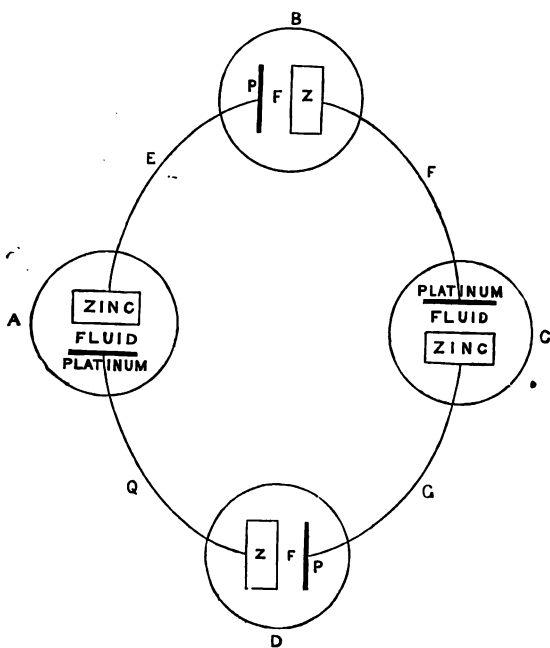
or observation a continual passage of this morphic heat, from the zinc plate losing or repelling it, or burning or shape-changing, to the platinum plate attracting the heat by an inherent power common to chemically athermic metals; and because the water in the galvanic cell cannot conduct heat, there is only one channel by which such a transit of heat from zinc to the platinum can take place, namely, through the wire that connects the two metals, zinc and platinum. And we accordingly, in this uniting wire, can see the heat by causing the heat-conducting wire to become white-hot, red-hot, or heat-dissipated, according to the amount of heat we force the wire to carry or convey. The course of this heat is therefore along the wire, and from the zinc repelling it to the platinum plate attracting it. And from the platinum the heat finally passes into the hydrogen, which the heat serves to transform from liquidity to gaseity, and the heat is thus carried away and equilibrium restored.

But we have still, in this single voltaic cell, the abstraction of heat from the zinc, which is therefore minus or negative as to heat; and the addition of this same heat to the platinum plate, which is therefore to the same amount plus or positive as to heat, and finally a transference of this heat from the platinum to the hydrogen, which thus also becomes positive, with that part of the fluid of the cell that hydrogen may pervade.

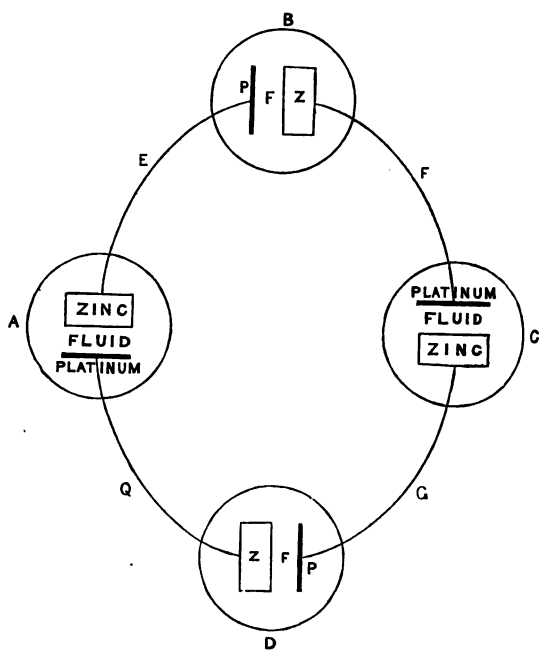
CHAPTER II.

LET now any number, such as four equal voltaic cells or cups, A, B, C, D (see the diagram on next page) be connected by four wires, E, F, G, Q, the zinc plate in the cup A, with the platinum plate of its neighbour at B by the wire E; the zinc plate in the cell B, with the platinum plate of its neighbour cell at C by the wire F; the zinc plate in the cell C, with the platinum plate of its neighbour cell D, by the wire G; the zinc plate at D, with the platinum plate of its neighbour cell at A by the wire Q. Then the latent heat of metallicity produced by the combustion and shape change of the zinc plate at A passes along the wire E to the platinum plate attracting it in the cell B, where the heat vaporises hydrogen, with which the heat is carried away; but this hydrogen in the cell B has been furnished by the oxidation of the zinc in B, and thus this zinc in the cell B is forced to oxidise just as the heat yielded by the zinc plate in the cell A will allow it. But the heat of the burning zinc in the cell B passes along the wire F to the platinum plate in C, where the same thing happens as in B, and so on throughout the whole cups of the battery.

DIAGRAM



DIAGRAM



Hence it arises that the heat that vaporises hydrogen in any of the cells comes from a neighbour cell, and it is thus that a system of checks is established between every cell of a battery, one cell checking another, nay, one cell checking all, and all checking one throughout the whole battery. So that, were we to substitute any of the cells by a weaker one, we could thereby weaken the whole of the cells, and diminish the quantity of the heat in currency through the whole battery.

Again, the heat travelling along a single wire that connects two cells, say the wire E, must be equal to the heat travelling along any other single connecting wire, say F, for the heat on both these wires has equal causation and effect. Let us sum up the whole quantity of heat existing in the entire battery of the diagram, and we find the heat equal to that of four cells, those namely at A, B, C, D. On any single wire we have the heat quantitatively of one cell, on the *four* wires the heat of the sum of four cells; it is true that this four-celled quantity of heat is not in circulation through and through the cells of the battery, but this four-celled heat's influence tells on each cell, owing to the system of check of one cell on another, one cell on all, and all on one. We have therefore upon the heat of one cell, say A, that travels along the wire E in the diagram, the combined influence or pressure of the heats of the three other

cells, B, C, D ; and the more we increase the number of these cells the more will we increase the amount of this influence or compression on the heat of a single wire ; and as we cannot increase the quantity of the current heat in any single wire by any increase of number of the cells, we must increase the compression of this heat by an increase of the number of cells, and by this compression we cause the morphigenic heat to assume a certain amount of condensation, and therewith the properties or characters of electricity.

In this view of the phenomena of the galvanic battery there is no current of heat supposed to traverse the fluid of the cell. For if it be a heat current, how can it ? The fluid of the cell does not conduct it, gives it no passage. But the current of heat is supposed to start from the zinc producing and repelling it along the connecting wire to the platinum of the neighbouring cell attracting the heat, thence the heat passes into the hydrogen of the same neighbouring cell, and disappears in making that hydrogen a gas. It happens, therefore, that the surface of the platinum becomes coated by a film of bubbles of free hydrogen gas ; now a gaseous body, even though metallic, is a bad heat conductor, therefore this film of gaseous hydrogen on the platinum plate impedes the ready transmission of heat from the platinum to the still unevolved hydrogen ; but not only that, the surface of the platinum plate is thus coated by the most thermic

al in the world, where the most athermic of metals that is required. Instead, then, of having a plate posed of athermic platinum, we have a plate, so to speak, of the very thermic hydrogen; we have the most heat where alone the greatest cold ought to be, and we have consequently very great disturbance of the battery's action, or complete stoppage of it. To obviate this, some other metal than hydrogen, some other metal belonging to the platinum class, or at least some metal more athermic than zinc, must be reduced to the platinum plate, and this Daniell contrives by placing copper instead of hydrogen. Or the surface of the platinum may be so roughened as never to become coated by gaseous hydrogen, since roughened platinum casts the gas very fast off.

Having thus studied a number of the phenomena of the voltaic battery, we stop again to ask ourselves what is the principle therein evolved? And we give as answer that it is Morphigenic heat, Heat of chemical transformations. This heat, as we have seen, has many curious and striking properties of its own; but by causation, this heat, in a galvanic battery, may be held ordinary morphigenic caloric, for it springs from a burning, shape-changing metal; but by concentration this same principle in question is electricity, for under special compression it becomes electricity. So that we have, on the one hand, morphigenic heat closely related by birth to heat, and by growth

or peculiar development to electricity. Morphigenic heat thus occupying as it were a middle place between the two, and establishing the long sought and confidently expected link between electricity and heat. For morphigenic heat begins by being common heat, is born heat, and ends by becoming or growing up to electricity; or, in shorter terms, ordinary Heat, Morphigenic Heat, and Electricity, are phases of the same radicle principle.

I repeat that it seems to me impossible to doubt that the principle set in motion in the galvanic battery is morphigenic heat, an object, as far as I know, new to science. By causation this principle is closely related to ordinary heat, and therefore it is readily brought to show most of the properties of common caloric. But, nevertheless, this principle differs from common heat in that the principle travels through its conductors, a wire for example, with much greater speed than common heat. Morphigenic heat differs also from latent heat, to which, however, of all things it bears the closest resemblance, in that morphigenic heat is more natural, and therefore more completely, perfectly, and persistently latent than latent heat itself. Morphigenic heat differs, however, by far the most from the electricity of the friction machine, inasmuch as in a single isolated cell of a galvanic battery this principle of morphigenic heat presents not a single characteristic unequivocal

property of friction electricity. But still we know that if we multiply the number of galvanic cells, thus, as we have seen, compressing the morphigenic heat, the consequent condensation of the morphigenic heat gives it electric powers. Therefore, because this morphigenic heat differs from ordinary heat and electricity, but only by differences that are easily effaceable or explicable, it seems to me that we must conclude that morphigenic heat is a phase of common heat and of electricity.

CHAPTER III.

IN a single isolated galvanic cell the principle existing has not one unequivocal property of the common forms of electricity, and indeed we have seen that it is morphigenic heat that has not yet been compressed into assuming the electric phase. When we attempt, therefore, as is usually done, to explain the phenomena that are present in this single isolated galvanic cell by the laws of friction electricity, without paying attention to the evident exceptional nature of the case, or laying any weight on the concurrent chemical phenomena, we are at once landed into difficulties and contradictions: these difficulties the clear-brained and candid detect and acknowledge; the majority overlook, ignore, or evade.

Upon matters that can be decided by the crucial test of experiment, and about which, therefore, there cannot be a doubt, such as the electric states of the zinc and platinum plates and the fluid of the cell, the old interpretation and the new attempted in this disquisition are and must be at one. For both the old and the new theory and experiment make out that

the zinc is negative, and the platinum and the fluid of the cell positive, as to heat and as to electricity. About the direction of the current between the zinc and the platinum plates, and the current's existence through the fluid of the cells, two things not so easy as at first sight seems of direct and satisfactory proof, the old and new interpretations are at complete variance. By the new interpretation proposed in these pages, the current of the principle in the galvanic cell passes *from* the zinc *to* the platinum, exactly the reverse of the old ideas. But the new theory seems to me, of course, the more reasonable. For we find the zinc of the galvanic cell, according to every theory, old or new—better still, according to experiment—is in the minus state, which means, if it means anything, that something has been subtracted from galvanic zinc. Galvanic zinc has always the sign of subtraction attached to it. What has become, then, of this something that has been so subtracted from the galvanic zinc? Surely it must have gone somewhere.

To galvanic platinum, on the contrary, is attached always the plus mark, the sign of addition. Whence has come this something that has been added to the galvanic platinum?

By the new theory, the way of answering these questions is to suppose that which has been added to the platinum has been taken, through the wire, from

the zinc; for the subtraction from the galvanic zinc and the addition to the galvanic platinum are synchronous and equal, and we know that the platinum is quite as ready for the addition as zinc is for the subtraction; and, besides, an excellent means, the wire, exists for effecting the subtraction. In the old theory it is said that that which is subtracted from the zinc is in totality added to the *fluid* of the cell, and from the fluid it is added completely or in totality to the platinum. But this is impossible. For if we by this old theory analyse the electrics of a galvanic cell, we find that in it there are two metals; one zinc, negatively electric, and the other platinum, non-electric, both immersed or in contact with a fluid positively electric. In these circumstances, by all the known laws of electricity, all the electricity of the positive fluid must at once be discharged upon the negative zinc in contact with it. Not a particle of electricity can in this case find its aberrant way to the non-electric platinum. Positive electricity in contact with two metals, platinum and zinc—the first non-electric and the second negatively electric—will certainly, if electric laws lie not, not go to the non-electric metal platinum, but will be at once and in totality discharged into the negative metal zinc. So that, if the old theory is held, all the electric actions of a galvanic cell would be confined to electric discharges from zinc to the fluid, and from the fluid

back again to the zinc. But this does not correspond to the facts observed; is in direct opposition to the facts observed. By the new theory, it is clear that the effect of the disposition of matters in the galvanic battery is to render zinc, when action commences, minus or negative, that is, to subtract something from zinc. It is evident, therefore, that before that action began zinc must have had the thing taken from it when the action was established; you cannot subtract one from nothing. Zinc of the battery must have had electricity or heat latent in it before action, in order to have yielded it during the action of the battery; and because platinum received the thing added to it so readily, there must have been rather a deficiency of the thing added in platinum. And this we know is the case, for we know by our axioms that zinc is a thermic metal, and has therefore heat, and platinum is an athermic metal, and therefore is deficient in heat. And all this but means that the positive state of platinum and the negative state of zinc are a second step or scene in the phenomena of the galvanic battery, the first step or scene being exactly the reverse—things commencing by zinc existing positive and platinum negative, Thus—

First scene in the phenomena of the galvanic battery consists of a quantity of electricity, or heat latent in zinc, and deficient in platinum—zinc being

thus plus, and platinum minus as to electricity or heat.

Second scene in the galvanic battery consists of zinc losing its latent electricity or conditional heat to change shape into oxidity or ashes, zinc thus getting the losing or subtraction sign of minus upon it—that is, becoming negative; and this lost zinc heat passes through the wire—its by far easiest way, and therefore only way, to the platinum, which thus gains heat or electricity, and acquires the increase or plus sign upon it, or becomes positive.

Third scene of the galvanic battery consists of this electricity's discharge from the platinum to the hydrogen of the fluid, and the equilibrium restored by the escape of the hydrogen.

In short, in the galvanic battery, by the new theory, the platinum is simply charged electrically by the zinc through the wire, the easiest way, and discharged by the hydrogen, which escapes forthwith from the field of action, and thus restores the equilibrium. And that the current comes from the zinc, and goes along the wire to the platinum, we have absolute ocular proof. For in the case of the two charcoal points, in what is called the "voltaic arc," it is that charcoal point that is connected with the burning zinc pole of the battery, and that therefore by the new theory first receives the heat—it is that very zinc-connected charcoal point that first becomes

white hot or incandescent. By the new theory it must be so, for by that theory the heat must first reach the charcoal point connected with the burning zinc. Theory and fact are therefore in perfect accordance. The new theory says that that charcoal point that first receives the current, first shows it by becoming incandescent. The new theory says that that charcoal point which the heat current first reaches first becomes heated or white hot, and what the new theory says accords with what the Fact indicates.

The actual fact, however, obliges the old theory to say that that charcoal point that last receives the heat current, first shows the current—first becomes affected by it.

Incandescence of the charcoal points is undoubtedly the effect of the presence of the electric current. Where the current passes there is incandescence. Where therefore there was first incandescence, there assuredly the current first passed. But incandescence first occurred on the zinc-connected charcoal point, therefore the current must have come from the zinc. I can see no way or loophole through which we can escape from this conclusion.

Of the presence of the current through the fluid of the cell there exists not the slightest proof; but, on the contrary, everything militates against such an idea. For, first of all, the fluid does not conduct heat or electricity of such low tension. Moreover, if we

assume the existence of an electric current through the fluid, we must make that current pass from the zinc to the platinum—that is, from negative to positive, and, besides, through a very bad conductor, which seems absurd. By no known law of common electricity, as viewed by the old theory, can it be explained why zinc exists in a negative state being plunged in, and thereby in close contact with, the positive fluid of the cell, without instantaneous and equilibrising discharge taking place between the *closely* contiguous negative zinc and positive fluid. Indeed this is utterly at variance with the law of common friction electricity. Some electricians acknowledge this, but content themselves by stating that this electric anomaly *must* exist, although it be impossible at all to square it with electric law. But the new theory teaches us that there is no such anomaly, and by taking into account, as most decidedly ought to be done, the concurrent phenomena of the galvanic cell, the new theory finds that the positive state of the fluid of the cell depends on the positive freed hydrogen that pervades that fluid, and this positive hydrogen is continuously and rapidly escaping out of the fluid and the sphere of the negative zinc, with which, therefore, hydrogen when thus escaping can little permanently interfere.

When more cells than one are concerned, the old theory's explanation of the direction and course of

e current of the battery is still, if possible, more confused, contradictory, and unsatisfactory.

The explanation is, that, starting from the positive platinum plate of the cell A, as in diagram, page 114, the electricity goes to the negative zinc in the cell D, through the wire Q, then the electricity passes through the fluid of the cell D to the positive platinum plate in D, and so forth. That is, we have to conceive such a strange, inexplicable, electric current as one starting from positive platinum, then going through the wire to negative zinc, thence passing on, without diminution, still as positive electricity, through a bad conducting fluid of the cell to the positive platinum. That is, a through and through electric current, sometimes positive, at others negative, passing at times from negative to positive, then from positive to negative; now choosing good conductors, and traversing them, then at the very next step preferring bad conductors, and passing through them with like ease. Surely a jumble of things difficult, nay, impossible, to unravel or explain by electric laws, our only permissible guide in the case. Again, we do not increase the quantity of the current on any given wire by increasing the number of cells, which we must do if the old theory were true—that is, if the same current passed through and through along the entire number of cells; and this last objection to

the old theory seems to me, even singly, quite fatal to it.

By the new theory we know at once that we do not increase the quantity of the current on a single wire, however numerous we may make the number of the cells; for in the galvanic battery, by the new interpretation, the current is not a single long one, reaching from one end of the cells of the battery to the other; but in the galvanic battery, by the new theory, there are as many distinct currents as there are cells, the current passing only between two neighbouring cells, and being limited to these two neighbouring cells, originating in the zinc of the one and terminating completely in the platinum and hydrogen of the neighbouring cell. But though the current be thus quite limited to two neighbouring cells, still its very existence depends on the currents of all the other cells of which a battery may be composed. One current therefore comes to be subjected to the influence or pressure of all its brother currents of the battery, and it is under this pressure that the current assumes electric properties; for, as you clearly cannot increase quantity in the current by increase of cells, you tend to increase tension.

The properties of common friction electricity, pure and simple, therefore, clearly suffice not for the distinct conception or the explanation of the phenomena of the galvanic battery; and the reason is, that elec-

ricity in the galvanic battery is for the most part in a *phasic* state—that is, not electricity proper, but its phase, which we have ventured to call morphigenic heat. And thus we require the knowledge of the properties of this morphigenic heat, together with those of common electricity, in order completely to master the actions going on in the galvanic battery.

We shall therefore, in this disquisition, assume it as established that the current of morphigenic heat or electricity springs from the zinc, passes along the wire connecting two cells to the platinum plate of a neighbouring cell, and from the platinum to the hydrogen of the same cell with which the heat is carried away, and equilibrium results. Consequently, there is no current of heat or electricity through the fluid of a galvanic cell ; in fact, as has been ere now said, the fluid does not conduct it. Consequently, also, there is no current traverses any liquid electrolyte a voltaic battery is decomposing, for the electrolyte's decomposition would then occur wherever the current passed, and not alone at the electrodes : as indeed happens always with a current of machine electricity traversing and decomposing water.

CHAPTER IV.

THE phenomena in the fluid of a galvanic cell are much more complex than the simple passage of a so-called electric current through the fluid of the cell, and are thus attempted to be explained.

The fluid in a galvanic cell may be considered, in order to facilitate description and comprehension, to be but water, that is, a compound of oxygen and hydrogen. Before their combination, oxygen and hydrogen, by our axioms, attracted each other, for they had unequal heats. But hydrogen loses heat, and thereby attracts oxygen, and combines with it, and matters are then quite reversed. Hydrogen and oxygen, combined or as ingredients of water, repel each other, because they then have equal or like heats. Hydrogen of water also attracts the heat it lost at its combination with oxygen, and by the law of reaction the heat itself will also attract the combined water hydrogen. So that there exist in oxygen and hydrogen ingredients of water in the galvanic cell, a tendency to go opposite

ys, a repulsion, a polarity of repulsion ; and in the hydrogen of that water there exists an attraction for at, and also an attraction of heat for the hydrogen.

this thus constituted water of the galvanic cell, and opposite each other, a heat-discharging metal, ic, and a heat-loaded metal, platinum, exist also ; that is, a metal, zinc, attracting oxygen, and a metal, atinum, in virtue of the heat that loads it, attracting hydrogen.* But it is evident that the presence of oxygen-attracting zinc and hydrogen-attracting platinum, facing each other in the water of the galvanic cell, strengthens greatly the tendency to go opposite ways—the repulsion natural to combined oxygen and hydrogen of the water of the voltaic cell ; for the hydrogen pulled to the platinum, and oxygen pulled to the zinc, are thereby dragged in opposite directions, and the zinc and the platinum in the cell are right opposite to each other. So that there is a double force acting strongly for the disruption or pulling asunder of the galvanic cell water's ingredients—namely, their own mutual repulsion, and the zinc and platinum attraction, acting so as to coincide with and favour the mutual repulsions ; and to complete matters, the heat on the platinum that attracts the hydrogen gives it the means of escaping or transforming from hydrogen's water allotropy ; so that, in these circumstances, water's two repellent ingredients, oxygen

* See page 19.

and hydrogen, separate, and water is, as it is termed, decomposed.

You have not necessarily produced any molecular current in this voltaic water. Examine, lighted up with a beam of concentrated light, with the highest powers of the best microscopes, this very water of the voltaic cell, the field of these seemingly mysteriously complex phenomena, and no difference will be perceived between the voltaic water and any other quiescent water ; for you have not produced, by all your manipulations, in the water of the voltaic cell in action, anything new ; you have only strengthened greatly, in the oxygen and hydrogen of that water, their pre-existing polarity of repulsion. In short, this water in the cell of a voltaic battery in action differs from any other water only in the greater intensity of the repulsion of its ingredients, oxygen and hydrogen ; a difference invisible to the eyesight, and apparent only to the mind.

We seem now beginning to obtain a clearer glimpse of the nature of galvanic chemical decompositions. Such decompositions are entirely polar. Galvanism acts, but in a more picturesquely-evident way, as we saw heat pure and simple act ; and so galvanism ought to act, seeing that galvanism and heat are phases of the same thing, and both of them act by increasing the already existing repulsion in the ingredients of compounds, at the same time

giving them the means of chemical transformations. Thus, when incandescent liquid platinum is dropped into water, the great heat of the platinum acts first by intensifying the already existing repulsion of the components of the water, oxygen and hydrogen, because the heat intensifies that repulsion's cause, which is a heat cause, a heat equality ; but at the same time this heat of the incandescent platinum that increases the water's ingredients' repulsion, gives them the heat of chemical transformation, and so the ingredients must separate and transform, or water gets decomposed, as it is termed, by the incandescent platinum.

The decomposition of water in a galvanic cell is also an entirely polar heat phenomenon, but more complex : it is the tendency to lose and gain heat on two opposite heat-natured metals, zinc and platinum, that intensifies the polarity of repulsion in water's ingredients in the galvanic cell. First we have the platinum gaining heat, and therefore repelling oxygen,* and we have the zinc losing heat, and therefore attracting oxygen ; so that there are here three forces urging the oxygen to the zinc—platinum's repulsion, zinc's attraction, and the mutual repulsion of oxygen and hydrogen.

Platinum's gain of heat causes it to attract hydrogen, and oxygen's and hydrogen's mutual equality of heat

* See page 19.

repulsion drives the hydrogen also in the direction of the platinum. Repulsion of ingredients, the first step in chemical decomposition, is thus most strongly and effectually brought about in the water of the galvanic cell; but the very means—namely, heat—that has intensified in the cell-water's ingredients this repulsion, the first step towards chemical decomposition, furnishes the ingredients also with the means of taking all the other steps in chemical decomposition—that is, with the heat of chemical transformation. So that it is no wonder that, in these circumstances, that most stable compound, water, becomes decomposed or yields up its ingredients.

The heat current—the electric current—does not penetrate, much less traverse, the water of the cell. The current cannot do it, but the current's polarising influence is felt, not so much by the water itself, as by the water's ingredients, from one plate of the voltaic cell to the other, or, as we shall soon see, from one electrode of an electrolyte to the other.

I have thus traced, step by step, conditional heat, from its quiescent, latent state, in chemical bodies, through its various changes, and having finally tracked this heat to the galvanic battery, we find that this heat that plays such necessary parts in every chemical combination has yet another mission in Nature, for it is capable of assuming the *Electric phase*.

All along, during our study of this morphigenic

heat, its likeness to electricity could not have failed to strike us. This heat's accumulation, discharge, and equilibrium, in chemistry, vividly resemble, nay are identical with, the parallel electric actions. The attraction and repulsion induced by difference and similarity of conditional heat are electric, and could not but be electric.

In other words, the attraction and repulsion of chemical heat electricity—that is, chemical electricity—are quite similar, parallel, identical with those of friction electricity. Friction electricity and chemical electricity, of the same name and nature, repelling each other: electricity and chemo-electricity, of opposite name and nature, attracting each other; nothing therefore more easy to perceive and to grasp than the complete identity of these actions of electricity and of chemo-electricity. But it is also quite easy to understand why chemo-electric discharges—(that is, the discharges of that we have up to this called morphigenic or conditional heat, but what now we may call also chemo-electricity)—should be, not indeed different, but infinitely more difficult and complex than the discharges of our more familiar friction electricity.

Friction electricity is an artificial temporary production, a thing literally and truly on the very surface of bodies, a thin pellicle of a principle evenly spread over the external superficies of electrified

bodies ; hence discharges of friction electricity, its changes and equilibria, are the easiest of matters.

It is very different, indeed, with chemo-electricity ; it is the natural enduring state of all chemical molecules or atoms, alike of the most central and deep and of the most peripheral and superficial. Hence, chemo-electric discharges, and, still more, chemo-electric equilibria, must necessarily be much more intricate and difficult than those of friction electricity. But, for all that, they do not cease for a single moment to be identical.

So, all along in our description of chemical phenomena, the word Electricity might have been, *mutatis mutandis*, substituted for the word chemical Heat.

The fact of the identity of heat and electricity considered as established, it becomes much easier to understand and describe the phenomena of the galvanic battery.

In the cell of a galvanic battery we have two metals—zinc, that is thermic and positive, and platinum, that is athermic and negative. The thermic metal, zinc, has the constant tendency of its class to cool, to repel, to discharge heat or electricity ; and the athermic metal platinum has also the constant tendency of its class to attract or acquire heat—to become positively electrified. You place these two metals in a galvanic cell, where they can follow this

their strong bent, and you connect the two metals, zinc and platinum, by wire—that is, by an excellent conductor of heat and electricity; and the two metals, in these circumstances, do follow their bent. The thermic or positive metal zinc loses its heat, discharges its electricity, just in the same proportions as the athermic negative metal platinum attracts and gains it; in other words, there is a discharge of electricity in the easiest way—that is, through the wire that connects the two metals—from the plus zinc to the minus platinum, the one metal, zinc, repelling its electricity, and the other metal, platinum, attracting it. And it is evident that you facilitate the loss of heat or electricity from the thermic zinc, if you connect that thermic zinc with the cold platinum that attracts heat, for there will then be two forces taking away the heat from the zinc wishing to lose heat—first, zinc's own repulsion for heat, and, second, platinum's attraction for the same heat; consequently, the thermic zinc, while connected with athermic platinum, will lose heat faster and more easily—that is, oxidise faster—than when unconnected with the athermic platinum, as we distinctly observe happening in the galvanic battery. The current of electricity sets from the positive to the negative. It must always do so. But then it is the zinc plate that is the positive plate at the outset, before the natural state of matters was

disturbed. The current then, at the very beginning, flows from the positive zinc to the negative platinum, and flows, as all electric currents must, through the easiest and most direct channel—that is, through the wire. And then matters are reversed, and the zinc plate becomes minus or negative to the same amount as it has lost to platinum, and platinum becomes then to that amount positive.

The positive zinc discharges its electricity on the negative platinum first, instead of discharging the electricity upon the negative hydrogen—that is, quite close to the zinc—simply because it is much easier so to do, the hydrogen being the worst receiver or attractor of positive electricity in the battery, or in the world, the platinum one of the best. And the electricity passes through the wire, and by no means through the fluid, because the wire is one of the best conductors of this electricity, and the fluid a bad conductor. From the positive surface of the platinum the electricity passes into the hydrogen, negative as much as its very positive nature allows, by allotropy. And the equilibrium is continuously brought about by the escape of hydrogen as gas. The electric or heat current has thus constantly passed, as it is bound to do, from positive to negative, from thermic to athermic. And equilibrium is established by the heat or electricity becoming latent or equilibrated in the molecules of hydrogen.

In the fewest words possible, I would say that the essential phenomenon of the zinc oxidation in the water of the galvanic cell consists of a discharge of electricity from the positive zinc to the negative hydrogen, hydrogen being negative by its combination water allotropy—but hydrogen is by far the most thermic metal known, and, in consequence, hydrogen's nature is that of a good giver but a bad receiver of positive electricity. If, then, when zinc is discharging its plus electricity into that bad receiver of plus electricity, hydrogen, the best of receivers of plus electricity, platinum, be connected with the zinc, it is natural that the plus electricity of the zinc should go first to the platinum—that is, prefer the platinum that attracts it, and avoid the hydrogen that in a measure or comparatively repels that electricity; and this the plus electricity does, and accumulates on the platinum till the feebler negativeness of the hydrogen thence takes it away.

When more than one cell are concerned in the voltaic battery, the explanation will be the following :—The plus electricity furnished by the zinc of the cell A (see diagram, page 114), and that must be discharged, has but three means of discharge accessible to it; the plus electricity from the zinc of A may be discharged at once into the hydrogen that exists in the water or fluid of the same cell at A; or

the plus electricity may be discharged through the fluid upon the platinum plate of the same cell at A ; or the plus electricity may be discharged upon the platinum plate of the neighbouring cell at B, with which the plus electricity furnishing zinc is connected by the excellent electricity conducting-wire, E. Of these three means of discharge, the electricity will take the easiest ; electricity mostly does. Now, the easiest discharge is into the platinum plate of the neighbouring cell at B, for thereto the electricity is most attracted, and has the readiest, easiest passage way, the metallic wire E. The plus electricity does not pass directly into the hydrogen of the water of the cell A, though the hydrogen be quite close to the plus electricity, because we know that the hydrogen is the worst receiver of plus electricity in the battery, in the world. The plus electricity cannot go to the platinum plate of the cell A, though platinum does attract it, because there intervenes between that platinum plate and the attracted plus electricity a bad conductor of this kind of electricity—namely, the fluid of the cell at A. The plus electricity of the zinc of the cell A has therefore no choice left but to be discharged through the wire E, upon the platinum plate of the neighbouring cell B, and on this platinum the plus electricity accumulates, until it forces its way, or is discharged into the hydrogen of the water of the cell B, and then complete equili-

brium results. But the discharge of electricity of the zinc plate at A depends upon the oxidation or shape-change of the zinc in the water of the cell A, and this oxidation of the zinc can only take place by zinc's displacing the hydrogen, so that to originate and keep up any electric discharge from the zinc at A there must be also a corresponding evolution of hydrogen at A. But in the cell at A there exists no heat for chemical transformation of the hydrogen, for the zinc at A, that ought to yield this heat, has sent it through the wire E to the platinum at B, the neighbouring cell; so that the electricity or heat for the transformation of hydrogen in the cell A comes from the zinc plate in the cell D, which zinc plate at D discharges electricity upon the platinum plate at A through the wire Q, and thence into the hydrogen at A, for precisely the same reason that the zinc plate in A discharged, through the wire E, its electricity into the platinum at B.

So that the electric discharge of A, B, and D, nay of C, nay of all the cells of a battery, all depend closely, indispensably, one upon another: A depends upon D, and B depends upon A, and so on throughout the entire series of the cells that any given battery may have; but it is likewise clear that if the discharge of A depends on that of D, and if the discharge of B depends on that of A, the discharge of D will also influence the discharge of B by D's

influence on A's discharge, and by this chain of reasoning it can be made out that one cell influences every cell of the battery, and that all the cells collectively influence, back, check, compress, one solitary cell; so that, upon any of the connecting wires we may take, since that wire is transmitting the heat current of one cell, we may at pleasure get the concentrated effects or pressure of an entire battery—the larger the battery the greater the pressure—and it is this pressure that produces, when it reaches a certain intensity, electric properties in the principle called into action in a galvanic cell.

So that the course of the electric current in the galvanic battery, as made out by the speculations in this disquisition, is, first, from the positive zinc, then along the connecting wire to the platinum, which thus becomes positive, and discharges upon the hydrogen, which becomes also positive, but escapes out of the field of action. When hydrogen does not escape readily, a disturbing cause is introduced, of which we have already given all the explanations that seem necessary in an earlier part of this paper.

The current exists only on the wires connecting the zinc and platinum plates of a battery, and the quantity of the current on one wire must be equal to the quantity of the current on any one of the others, for to this result must the concatenation of the cells

lead ; nor can this quantity of the electricity be increased on any of the wires by fresh additions of cells ; the quantity of electricity is not increased ; the tension is ; nor can we expect that the compression or tension would increase if quantity increased also. In the fluid of the galvanic cell there is no current, but only its attracting or polarising effects upon the ingredients of the chemical compounds of the cell.

So that when zinc deoxidises water, zinc is compelled to displace water's hydrogen—that is, to evolve that hydrogen as gas ; that is, to discharge heat into hydrogen, and, if heat and electricity be convertible terms, to discharge electricity into hydrogen. Now it happens, as we have just seen, that this hydrogen is the best giver and the worst receiver of this electricity in the world, so it becomes possible to deviate this electricity that zinc is giving to hydrogen, by bringing platinum into competition with the hydrogen for the heat that zinc is discharging ; and when you do that, the victory is always to the platinum. And it is only this bad reception of hydrogen for electricity that renders this deviation of the electric current along the wire, first to the platinum, and then, to be sure, to the hydrogen, at all possible. For if the hydrogen received this electricity at all readily, hydrogen would infallibly take the electricity right away from the zinc with

which hydrogen is in close contact. I repeat, if hydrogen were a better receiver of plus electricity than hydrogen happens to be, you could not make the heat discharge from the zinc into the hydrogen take the roundabout course it does in a galvanic battery—from the zinc, along the wire, first to the platinum, and, at the very last, to the hydrogen; that is, you could not have a galvanic battery at all.

If, for example, zinc reduce any other metal but hydrogen—if zinc reduce a metal that is but a fair receiver of electricity, such as lead—the heat phenomena are the same; there is a discharge of heat from the burning zinc, in order that zinc may undergo its oxide heat-shape, there is an absorption of this morphogenic heat, discharged from the zinc by the oxide lead, in order that the lead may undergo the transformation into its metallic form. In short, there is just what happened with the zinc and hydrogen—namely, a discharge of heat from zinc into the lead. But then there is this great difference, that the lead receives this zinc-heat so well that you cannot make the heat about to be discharged into lead by zinc, in the lead-tree experiment, take any roundabout course, by connecting zinc, reducing lead with platinum; for any superior attraction for heat platinum may have over lead is quite counterbalanced by lead's being close or in contact with the heat-giving zinc. And in these cases the heat-discharges take

always directly from the discharger, or giver to
ker, from the zinc to the lead, and therefore
eat-discharge we cannot utilise. That is, we
form a voltaic battery of such a combination
of lead and zinc in the lead-tree experiment,
gh by most it is acknowledged that the dis-
ent of lead by zinc in lead solutions is quite
al.

CHAPTER V.

It remains for us now briefly to study chemical decomposition as effected by the voltaic battery.

The substances decomposable or decomposing by galvanism are called conveniently electrolytes; the decomposition itself electrolysis; and the extremities of the two wires, plunged opposite each other into the electrolyte, and that come, one wire from the zinc the other from the platinum plate of the battery, and that thus are said to carry the electric current into the electrolyte, are called electrodes.

The best, or indeed the only way of viewing electrolysis, is to consider the electrolyte, with its fluid and its two opposite electrodes, as but another cell that has been added to the battery. The electrolyte itself corresponds to the fluid of a cell; the two electrodes correspond to the two plates of the proper or true galvanic cell. But then it may be, *in limine*, objected that the two electrodes cannot correspond to the two plates of a galvanic battery, because, in the true galvanic cell, the two plates are of different metals, zinc and platinum; whereas, in

the electrolyte, the electrodes are both the two made of the self-same metal, platinum. This is true ; but then these two platinum electrodes are subjected, when connected with a battery, to an inductive pressure of the whole battery, and thereby these two platinum electrodes become functionally, potentially, virtually different, the one platinum electrode from the other. And this is easily enough shown by testing them with a galvanoscope, when one of these platinum electrodes is found plus, the other minus, as to electricity or heat. In other words, that one platinum electrode corresponds to zinc, and the other to the platinum plate of the common galvanic cell ; and this, be it well understood, is not a matter of assumption but of fact.

This has been termed the polarisation of the electrodes. And I am aware that the current between the electrodes must be in an opposite direction to that of the battery when the electrodes are disconnected from the battery and joined together, and this arises simply because the current must always pass from the zinc, or what corresponds to zinc, to platinum, or what corresponds to platinum.

One electrode or plate of the electrolyte cell, though really made of platinum, may thus be proved virtually or functionally zinc, and the other, its fellow, platinum electrode, virtually more platinum in some respects than it is when out of an electrolyte.

I will therefore always call that electrode that is connected with the platinum plate of a battery the zincoïd or athermic electrode, or electrolyte cell plate, because there is no heat in it, its heat being always given away to the platinum plate of the battery to which it is attached, and because this said electrode occupies zinc's place were the electrolyte a mere additional cell of the battery. I will call the electrode connected with the zinc plate of the battery the thermic or platinoid electrode of the electrolytic cell, because this electrode receives all the heat of a zinc plate of the battery, and because it occupies platinum's place were the electrolyte to be esteemed one more cell added to the battery. We have thus one of the electrodes, namely, the one we are going to call the zincoïd, though really made of platinum, and thus inoxidable, assuming, by virtue of its position and consequent induction of the whole battery upon it, some of the properties of an oxidable metal. That is we have an inoxidable metal becoming somewhat like an oxidable metal. And this needs not so much astonish us if we recollect that an oxidable metal, such as copper, under a like pressure of galvanic induction, that is by occupying the place of an inoxidable metal in the plan of a battery, becomes, as long as the copper keeps such a position, really inoxidable.

It was known and proved that an oxidable metal, copper, could be made inoxidable by the induction of

a galvanic battery; we now find also that an inoxidable metal, platinum, may be made to assume the office or some of the properties of an oxidable metal by the galvanic battery, as happens to the zincoïd electrode made of platinum in any electrolytic cell. So that electrodes, even when both are made of the same metal platinum, or any other metal or conducting substance, must be held as one functionally zinc, and the other platinum. That the actions in the galvanic cell fluid are quite analogous to the actions in the electrolytic fluid is abundantly proved, by simply stating the fact that it is electrolytes alone that are available in the cells of a galvanic battery for the production of galvanic electricity. And it is clearly because of this very close analogy that must exist between the action in the electrolytes and in the galvanic cells proper that galvano-chemical compositions are limited in number and variety. It is not, as is generally stated, because certain liquids do not conduct the galvanic current that they are not decomposed, for there are liquids that conduct galvanic currents without decomposition, but it is, on the contrary, because the chemical acts of those indecomposable liquids have no analogy, no correspondence, with the chemical acts of galvanism. Those indecomposable liquids cannot be coaxed or forced to form an electrolytic cell.

If the electrolyte ought to be by rights but

another cell that has been added to the battery, then the liker the electrolyte be to the battery cell the better, and this is most assuredly found to be the case.

How then can you expect that when you have made both the two plates or electrodes of the electrolyte, or what I call the electrolytic cell, of the same chemically inactive metal platinum, and plunged them into an inactive fluid (water), that this strange electrolytic cell thus made should perform analogous acts or functions to those of a galvanic cell? But it is exactly this that you most assuredly do, when you, using platinum electrodes, attempt to electrolyse pure water—a thing of the most extreme difficulty, and I believe impossible, if you could get absolutely pure water, in a very cold state and *in vacuo*, thus preventing any dissolution of air, etc., in the water.

But when, on the contrary, what I call the zincoid electrode, or what is at present called the positive pole of an electrolyte, is oxidable, or even covered with oxidable matters, of course such an electrolyte becomes like, or chemically identical with a galvanic cell proper, and electrolysis is much facilitated, as has been observed by Schönbein and others. Indeed, so close is the analogy between the electrolyte and a galvanic cell, that the electrolyte might be called the external cell of a battery. But if the electrolyte be as a galvanic cell, it follows that there cannot be a voltaic

current through and through that electrolyte, that is between its zincoid and platinoid electrodes, but only the attracting or polarising influence of the current on the electrolyte's chemical ingredients, as we saw happening in the galvanic cell. The natural polarity of repulsion of the chemical ingredients of the electrolyte is intensified by the attraction of the electrodes acting in opposite directions; and the electrodes alone, as a rule, being able to furnish to these ingredients attracted the means of chemical transformations, the ingredients are forced to go and to transform at the electrodes alone.

The single difficulty in trying to establish the identity of an electrolyte with a common cell of the battery lies in what I have called the zincoid electrode, if it be made of platinum,—because this electrode must always discharge, lose heat or electricity, or originate a current which this electrode must send to the platinum plate of the battery, this current or heat being necessary not only for the evolution and transformation of various substances from the surface of the said electrode, but also for the carrying on the action of the whole battery, for by the new theory there is a heat-current passing from the zincoid electrode to the battery.

Now we know that the great source of such heat as the zincoid platinum electrode has to discharge is chemical transformations; but platinum is very bad

at chemical transformations, so from this great source of heat a platinum electrode is often cut off. But still, whenever the electrolyte contains any ingredient having, or tending to have, the feeblest of actions on platinum, such as iodine, ozone, or oxygen of oxygenised water—that is any ingredient that can give any chance of chemical transformations to platinum—platinum does transform. For the induction of the battery is impressing upon a platinum zincoïd electrode a temporary transformable nature, just as a like galvanic induction impresses on copper a temporary intransformable nature. And a platinum zincoïd electrode transforming there is an end to our heat difficulties.

But still platinum as a zincoïd electrode often does not transform at all, and nevertheless actions take place on its surface that show the presence and intervention of heat—as when oxygen, as gas, is evolved from the surface of the zincoïd electrode made of platinum during the so-called galvanic decomposition of water acidulated with sulphuric acid.

In these cases the heat is derived from concurrent chemical transformations, not altogether in the platinum, but in the ingredients of the electrolytic fluid close to the platinum zincoïd electrode.

In order to comprehend this, let us take the electrolysis of water acidulated with sulphuric acid for study.

When we examine the so-called electrolysis of water we are struck by two facts—the very great difficulty, nay, impossibility, of electrolysing absolutely chemically pure very cold water *in vacuo*, and the seeming facility of electrolysing this same water after adding a few drops of sulphuric acid to it. But the reason is evident; it is simply this—that it is the transformations and decomposition of this very acid that follow. It is this very acid added that is decomposed, and not the water itself. It is the substance that is called hydrated sulphuric acid, whose composition is most readily indicated by symbols, $\text{SO}_4 + \text{H}_2$ —a compound of an equivalent of what has been called Sulphion SO_4 , and another of the metal hydrogen, that is $\text{SO}_4 + \text{H}_2$, sulphate of hydrogen.

SO_4 and hydrogen being ingredients in a compound, have like heats, and therefore a mutual repulsion,—have the tendency to go opposite ways, common to ingredients of all compounds. In $\text{SO}_4 + \text{H}_2$, sulphion and hydrogen placed as electrolytes, this natural repulsion becomes much increased by the attraction of the thermic platinoid electrode on the H or hydrogen, and the attraction in the opposite direction of the athermic zincoid electrode on the SO_4 , or sulphion. For the hydrogen being a metal, and heat conducting, belongs to the athermic class of substances; while sulphion, SO_4 ,

being acid, appertains to the opposite group of substances—the thermic group. Hydrogen will therefore attract and be attracted by the thermic, and the sulphion (SO_4) by the athermic poles. Hydrogen will therefore go to the thermic platinoid electrode, and will be there evolved as gas by the heat coming from the burning zinc plate of the battery. The SO_4 , or sulphion, will go to the athermic zincoid electrode; and as soon as SO_4 reaches the electrode, the SO_4 loses one equivalent of oxygen, and becomes SO_3 —common anhydride sulphuric acid; that is, sulphion SO_4 existing in hydrated sulphuric acid has a liquid thermic form, and passes into SO_3 —anhydride sulphuric acid, which is solid, or has a more athermic form; therefore SO_4 loses heat in passing into SO_3 —that is, in losing one equivalent of oxygen—and this heat the zincoid platinum electrode at once seizes and utilises for the evolution, as gas, of that equivalent of oxygen lost from the SO_4 , and for keeping up the action of the battery. But we do not see the SO_3 as a solid, for the very instant the SO_3 , or the solid anhydride sulphuric acid is produced, it combines with the water that abundantly surrounds it—for which we know it has the most violent attraction—and becomes again $\text{SO}_4 + \text{H}_2$ —(the common hydrated sulphuric acid)—and is again ready to undergo indefinitely the same round of composition and decomposition. So that $\text{SO}_3 + \text{H}_2$ (hydrated sulphuric acid) is continually decomposed

to $\text{SO}_2 + \text{O} + \text{H}_2$, and again reproduced at the zincoid platinum electrode; and it is these equivalents—two of hydrogen and another of oxygen—obtained, in fact, from hydrated sulphuric acid, that most erroneously figure as the oxygen and hydrogen of one equivalent of water that has been decomposed and electrolysed. The change of liquid sulphuric acid (SO_3) into solid anhydride sulphuric acid (SO_2)—a change from hot to cold—is what furnishes the platinum zincoid electrode with the heat that we see there, for this change only takes place on the surface of this electrode.

So that it is clear that the platinum zincoid electrode is put to shifts to obtain heat to carry on the action of the battery, and also for certain chemical transformations taking place near it—this electrode, when made of gold or platinum, being generally unable to furnish this heat by its own chemical transformations, as it were best to do. But as these zincoid reactions must be very repugnant to the athermic chemical nature of the platinum, they are all always with difficulty and imperfectly performed. I say with difficulty, for if it requires say *four* cells of a fair battery to decompose water, that is hydrated sulphuric acid, with platinum poles—that is, with a platinum zincoid electrode—but *one* cell of the *same* battery will suffice simply if the platinum zincoid electrode be taken away, and substituted by a zincoid electrode made

of any easily oxidable metal ; the electrolytic cell becoming then quite like a true galvanic cell. I say further imperfectly performed, for oxygen from a zincoïd electrode made of platinum is evolved as gas, whereas oxygen ought by right to have combined with and transformed the platinum, thus producing heat in a direct, easy, legitimate, regular way, for the purposes of the battery ; but as oxygen is evolved as gas, a good deal of heat is thereby used up and lost for the battery whose actions require it, so that there is apt to be a deficiency of heat at the platinum zincoïd electrode—the oxygen is there only partially evolved as gas, some of it remaining in a colder form dissolved in the water as a peroxide of hydrogen, etc. Regularity in the evolution of the oxygen from platinum zincoïd electrode being only obtainable by *heating* the electrolyte.

The polarity of electrolysis need not detain us long. It depends entirely on heat causes—namely, on the difference of heat of the two electrodes ; we have seen that the platinoid is the thermic electrode, for it receives along the wire the heat of the burning zinc of the battery. The zincoïd is the athermic electrode, for its heat is given away, sent on through its connecting wire to the platinum plate of the battery. The thermic electrode will therefore attract its opposite, that is the athermic ingredient of the electrolyte, hence the metals and bases which we have found

by our axioms athermic will be attracted to this thermic electrode, and will there make their transformations and appearance.

The athermic or zincoïd electrode will always attract its opposite, that is the thermic ingredient of the electrolyte, hence the metalloids and acids which we found by our axioms thermic will always be attracted by this athermic electrode or pole, and will there make their transformations and appearance.

The new theory, as it reverses the direction of the current, reverses also the names of the poles, and makes that pole connected with the platinum plate of a battery the athermic or heat negative pole, and the other zinc connected electrode the thermic or heat positive pole.

That an electrolyte acid, in the allotropy it exists in, while in combination with a base, that is in that acid's saline allotropy, should be forced by voltaic polarity or attraction to pass through sensitive vegetable colours without reddening them is no marvel; the contrary would be the puzzle, for in those cases the electrolyte acid, as it is passing through the colours, is allotropic: it is indeed saline, and not acid, for the acid has not yet obtained the heat of transformation, which heat the allotropically saline acid can only, as a rule, obtain at the electrodes.

But it sometimes happens that during electrolysis

the allotropically saline acid, traversing a solution of salt, does get the heat that is necessary for its chemical transformation into acid proper even before such an acid reaches the electrode, where, as we have seen, such heat is generally found. And this happens when the saline acid passes through the solution of a salt which the acid decomposes, and with the base of which salt that acid forms an insoluble salt; for in that case the base of the decomposed salt passes from a state of solubility into a state of insolubility, from a thermic into an athermic form, and loses thereby heat enough to transform the allotropic saline acid with which the base is about to combine into *un-allotropic* or acid proper.

Thus, when allotropically saline tartaric acid passes through, during electrolysis, the solution of the sulphate of silver, with the base of which the oxide of silver tartaric acid forms the insoluble tartrate of silver, when the saline tartaric acid, drawn by voltaic attraction or polarity, passes the sulphate of silver solution, the then soluble oxide of silver leaves the sulphuric acid, which it repelled, and combines with the passing tartaric acid, and in that last act the base oxide of silver becoming insoluble, changes into a colder form, and discharges heat into the passing allotropically saline tartaric acid sufficient for the conversion of that acid from allotropy to acid proper. And thus the heat that transforms the allotropic

saline tartaric acid into acid proper is obtained from the oxide of silver as it passes from solubility in the sulphate of silver into insolubility in the tartrate of silver—an effect independent of the action of the battery.

That electrolytes should be fluids is very easily comprehended, for in fluids alone can the molecular movements of polarity, of attraction, and repulsion, have free and perfect play.

One thing may strike us, that although heat takes such an important and fundamental part in every voltaic phenomenon, still there is very little heat actually visible, and only its effects. But this is explained by the fact that the heat in currency is analogous to latent heat,—nay, more latent than latent heat itself; and the heat being in a state of highest concentration, and so exactly meted out to the necessities of the case of the combinations and decompositions, that little heat is lost or makes its appearance. The heat's transformation effects using it all up.

CHAPTER VI.

IN recapitulation, I may state that we began by noting that each chemical element had its own peculiar, inborn, inherent heat, and we instituted rules, based upon the element's state, weight, and specific heat, for measuring heat's intensity, and for tracing heat's course in bodies during chemical action. By the help of these rules we reasoned out our first law—namely, that there was no chemical combination possible without change in the conditional heats of the combining bodies. We passed next to observe that molecular and somewhat persistent absorption, or discharge of heat in bodies, signified a change of form in those bodies, as when water became invisible steam ; as when the diamond became, in the voltaic arc, common charcoal ; or, finally, when gaseous oxygen and hydrogen became transformed into water. And we thus arrived at our second law of chemistry, that as there is no chemical action without change of heat, there is no chemical action without change of form, for there cannot be a radical, molecular, comparatively permanent change of heat without a

change of form. Hence we reasoned out the existence in chemistry of a heat of transformation, a morphigenic heat, often indicated to us or even seen by us as a flash of light and heat during chemical action.

So that heat was found to be that which gave the striking changes of shape so characteristic of chemistry, and these circumstances explain the constant presence and the frequent sensible appearance of heat during chemical acts. But we further found that not only does heat change the forms of chemicals, but it does more, it produces also the attraction and the repulsions of chemistry, these being entirely mechanical, and depending upon difference or equality of heat in the mechanically attracting or repelling chemicals. The greatest mechanical attraction existing between the extreme of thermism and the extreme of athermism, and mechanical repulsion depending on an equality of heat only found in chemicals when united; but we found, further, that Heat does yet more in chemistry, it produces chemical activity of bodies, and also their morphigenic power or shapecraft. These bodies that have the greatest capabilities of heat concentrations in their ultimate atoms, such powers being indicated by small weight and great specific heat,—such bodies as are hot-grained and hot-atomed having the greatest chemical shape-craft or morphigenic powers.

Armed with the result of these speculations, we

began the analysis of the phenomena of the galvanic battery. We found the chief phenomenon of the galvanic battery to be an oxidation of the metal zinc. We asked, what is the meaning of a metallic oxidation? and the answer by our axioms was that it was a burning, a loss, a discharge of heat of chemical transformation, very evident both when zinc oxidises in air and when zinc oxidises in water; for when zinc oxidises in air we see zinc burn—heat *in propria persona* is there, and when zinc burns in water we have present heat's most indisputable effects.

We thus reasoned out that what is developed by the burning shape-changing zinc in the galvanic battery cannot be anything else but the heat of chemical transformations, morphigenic heat, which is certainly not common heat, and as certainly not common electricity, but, in fact, a phase in a radical principle, common to both heat and electricity. We went on to explain the actions of the platinum plate on such a galvanic zinc oxidation, how morphigenic heat, discharged from shape-changing galvanic zinc, took a roundabout course along a wire, *via* the platinum, to reach its final, essential destination, the hydrogen, because platinum was a far better heat attractor and receiver of plus electricity than is hydrogen. One by one we went over the phenomena of galvanism, and tried to explain and clearly understand them. First, the imperfections of the old forms of the

batteries. The origin, course, effects of the current, the utility of the amalgamation of galvanic zinc. The rationale of the current's condensation by multiplication of cells. The phenomena of polarity in the fluid of the cell, the nature of electrolysis. The induced polarisation of electrodes. The transportation by electrolysis of acids through blue colours without reddening them, etc. etc.

If it be true or granted that any gaseous element is more thermic than any solid element ;—If it be true or granted that any light element is more thermic than a heavier one ;—If it be true or granted that an element with strong specific heat is more thermic than an element with weak specific heat,—then it follows that the elements are each in a different state of heat, and that they discharge or change heats when they combine or separate ; that they change form because they change heats ; that they attract because they have these different heats, and repel when they have equality or similarity of heat ; and finally, that even their chemical powers depend on heat ; and lastly, likewise follows that Heat and Electricity are one.

All this seems to follow in logical sequence, if the above three simple axioms be true or granted. But when the possibility of proving them true may be denied. And then we ask, are not the deductions and results to which these axioms lead of sufficient value to plead for the axioms' concession and adoption ?

Or do these axioms so far outrage truth, probability, common sense, as to be rendered inadmissible? I think not; for in establishing the conditional heat tests, I have merely stretched slightly Black's beautiful latent heat laws; and in using weight as a heat measurer, I have steered in the wake of those who adopt expansion for like ends, and surely the employment of specific heat, as a heat sign, vindicates itself without any apology.

But, nevertheless, there may be very many who hold these axioms as inadmissible or absurd; and from such we would beg an explanation of the phenomena of the evolution of hydrogen as gas in the decomposition of water, say by potassium. Is free hydrogen a gas? Is hydrogen combined with oxygen in water a liquid? If so, how can we boil the liquid hydrogen of water to steam or gas without heat? If this can be done, show us how. It may, however, be said that hydrogen is not a liquid in water; then what is it? Is it solid? Is it gaseous? It can only be one of the three. Again, is it wrong to consider the burning of potassium to be potassium's oxidation, —potassium's reduction to ashes, to potashes; and if it is not wrong, then burning consists in a reduction to ashes of the metal burnt; then reduction to ashes is burning, and therefore, when potassium is oxidising in water, as it is being reduced to ashes, it is being burnt. What then becomes of

heat of this combustion of potassium under
? By the ideas advocated in this paper, the
ing of potassium in water's oxygen gives the
for the boiling of that same water's liquid hydro-
potassium thus decomposing the water.

I have thus confined myself merely to three heat
erties of chemicals, their condition, weight, and
fic heat, but of course these are not the only pro-
es in chemicals over which heat holds sway.

An element's volatility is certainly a heat property,
we have seen that a metal's volatility influences
chemical actions, and disposes volatile metals to
r heat-shapes or glow-shapes, as happens with
mony, etc., which are thus enabled to combine
hydrogen.

No doubt an element's hardness, expansibility,
perceptibly influence its chemical behaviour,
these influences, I hope, will afford subjects for
al future study.

I have throughout this paper taken hydrogen for
tal, but this is no assumption of mine; hydrogen
een long by many considered a metal.

In this essay I can only cast a very rapid and
ficial glance at the thermal aspects of organic
istry. Chemical reactions in organic chemistry
only be studied through analysis, and never or
m by synthesis, hence part of their difficulty and
rity.

The extreme sensibility of organic compounds to heat, renders necessary for their profitable study a farther extension of our axioms, so as to form a more delicate heat-test or chemo-thermometer, since the rougher heat tests of inorganic chemistry clearly will not suffice us. But this invention and application of more sensitive heat-indicators demands more time, space, mental powers, and means, than I can command. And as the chief object of this imperfect effort is, if possible, but to *found* the study of thermo-chemicals, and to establish on chemical grounds the identity of heat and electricity, and of chemical and electric actions, I shall content myself with trying to prove that in organic chemistry the same heat-laws hold sway as in the inorganic.

It is well known that although organic compounds are very numerous, still all or most spring from three, or at most four, of the elements, namely, hydrogen, oxygen, nitrogen, carbon. Three of these elements, the gases hydrogen, nitrogen, oxygen, are the most thermic substances known; the fourth element, carbon, is *conditionally* the most athermic of the elements; but even in carbon, as we have seen, there exists powers of heat-conduction and concentration. And it seems to me to be yet another proof of the vast influence of heat in chemistry that three of the four elements possessing most shapecraft belong to the most thermic of known terrestrial substances. And

even carbon, though the most athermic conditionally of known elements, still is, as we have styled it, heat-conducting, very hot-atomed, and hot-grained. Between conditionally athermic carbon and these three very thermic gases, there exists the widest of heat gap or difference, and this means that carbon shall have the strongest and most perfect mechanical attraction for hydrogen, nitrogen, and oxygen, in all their forms and on every occasion, except, of course, when carbon happens to be united to them. That is, carbon with oxygen and hydrogen can always perfectly perform the first condition of chemical union, that is, mechanical attraction. So that in an organic compound of oxygen, hydrogen, and carbon, in which these elements are being separated, it will happen that the instant they separate, which they do by absorbing each its own amount of heat, they at once again attract each other; and, if the temperature be regulated, pass into a new compound instead of appearing in their simple naked elementary forms. Owing, therefore, to the perfection of this attraction between carbon, hydrogen, and oxygen, it happens that organic chemical separation partakes more of metamorphosis than decomposition, that is if the temperature be moderate and regulated.

If we examine the other heat properties of these four elements, carbon, oxygen, hydrogen, nitrogen, we

find them admirably adapted for the assumption of heat-shapes.

But then this very acute sensibility to heat of carbon, hydrogen, and oxygen, that renders them of such formcraft, of such amazing facility in the production of heat-forms,—glowshapes,—renders also of necessity all their compounds unstable when exposed to variations of heat ; this facility of assuming heat-forms of carbon, oxygen, and hydrogen, makes to them union and disunion, composition and metamorphosis, equally easy, when they are exposed to the cause that produces change of form, namely change of temperature. Kept out of great variation of temperature many organic compounds are stable enough, as cellulose, sugar, etc.

The proneness to decomposition in organic complex compounds therefore does not occur because of the weakness of the attraction between their ingredients; for I have argued that in the ingredients of no chemical compound is there attraction, but, on the contrary, a repulsion; but the instability of organic compounds results from the ease with which very thermic oxygen, hydrogen, and carbon, the chief ingredients in organic chemicals, change shapes at almost all temperatures.

So that I hope that it is evident that the chemical reactions of organic and inorganic chemistry are both based on the same heat laws.

By subjecting any organic compound to carbon, oxygen and hydrogen, a gradual increase in the amount of carbon, oxygen and hydrogen is observed according to the amount of gas employed. Initially these gases will take in some gas and in more abundance of the common amount of gas used—such as water and carbon and air in the case of the ultimate analysis of organic compounds.

The binary nature, true nature of combination and decomposition is characteristic of inorganic chemistry, and indeed is necessary a consequence of the electric and polar nature of these combinations and separations seems a first sign less conspicuous in organic chemistry. But this is more apparent than real, and arises chiefly from our utter ignorance of the way that nearly all the organic compounds are built up or formed. Hence the early efforts of chemists in the progress of chemistry is continually showing more and more that the organic compounds are made in the same binary dual-forming fashion as the inorganic—this is shown by methyl, acetyl, ethyl, amyl, and the organic acids and bases.

The fact that electricity is condensed and modified heat being granted or established, much light is shed on many branches of electricity. For example, cannot help being struck with the signs of heat influences in common atmospheric electricity. Thus the cloudless atmosphere is generally positively elec-

trified, particularly in its higher strata ; and this is what might be expected ; because, in summer, if the air in close contact with the earth gets heated, it becomes lighter, and thus rises to occupy the higher regions of the atmosphere ; in winter the cloudless air in contact with the earth will always be colder conditionally than the cloudless air of the upper strata, which last is more expanded and has higher specific heat.

It is also not difficult to understand why this positive state of the higher strata of the cloudless atmosphere should decline in intensity from noon to four P.M., for in these hours, of all the hours in the day, it may be expected that the conditional heat of the cloudless atmosphere should be more equally distributed throughout the atmosphere's entire bulk.

It is also easy to see why, the moment clouds appear in the atmosphere, there should commence irregularities in its electricity. The prevalence of the aurora borealis or polaris during the long arctic and antarctic nights is also explicable, the aurora arising from the intense and constant coldness of the air on the polar earth's frozen surface, which leads to an accumulation of conditionally-heated air in the upper regions of the polar atmosphere.

In thunderstorms we have the traces of heat influences to my mind quite visible. Thunderstorms

occur much more frequently in summer—that is, in the hot season—than in winter, the cold season ; in the hot tropics more than in the colder latitudes of the earth. Even in summer it is in summer's hottest, sultriest weather, that thunder most prevails. The clouds from which lightning is launched—that is, thunder-clouds—are large massive cumuli, that, even when spread over an extended space of the overhanging sky, shroud the landscape in darkness. The air is remarkably still, so that these clouds are not at all dissipated, or their latent heat carried away. Heat or electricity is discharged from such clouds when they undergo sudden and extensive condensation into rain, the clouds thus passing from the hot vapour form into the colder liquid rain form—from steam to water ; and we know that this cloud condensation into rain on thunderstorms is more sudden and greater than is usual from the character of the rain that then falls, for the thunder plump of rain is generally sudden and heavy, and the rain-drops are larger than common, and the rain is sooner over. It is evident that a great bulk of cloud vapour must be condensed to produce a streak of lightning, and a large vacuum is thus created, and the circumambient air rushing in to fill this vacuum, occasions the loud rushing noise of thunder ; for the sound of the thunder-clap does not to me appear altogether like that of a monster or giant electric

spark, for the electric spark gives a quick snap, which could never, by any augmentation of strength or loudness, come to resemble the long lasting, rolling, rushing roar of thunder ; for I have many times in the tropics heard a thunder-clap last, as timed with watch in hand, more than half a minute, while I have not heard the snap of the largest electric spark endure more than the briefest moment ; and I have then been also struck at the likeness, after the first great explosion, of the thunder noise to the roaring and rushing sound of high winds in a great hurricane storm. Again, during thundery weather the atmosphere all around has been surcharged with conditional heat ; further, the thunder-cloud, from its massive density, has a great deal of heat to discharge, or get rid of. The air is still, so that the heat cannot be carried away and spread over a large space ; it happens, therefore, that these massive thunder-clouds find it difficult to discharge such an amount of heat into such a conditionally hot, still atmosphere, such as exists in thundery weather ; therefore, in order to discharge at all, this conditional heat must get intensified and condensed—that is, become electric, or lightning—as, indeed, we saw conditional heat do elsewhere—that is, in the galvanic battery—and the electricity then passes into the earth, for at the earth's moist surface there is during thunderstorms, evaporation going on—the very opposite of

what is taking place in the earth's atmosphere above.

The minute sifting, exposition, and consequent clear understanding, of chemical acts, may be useful in conducting the various processes by which chemistry daily ministers to human wants and well-being, and also in enabling us to solve some of the problems of the Chemicals of Physiology ; and if of Physiology, then of Pathology ; and if of Pathology, then of Therapeutics,—an art of some importance to ailing mankind.

THE END.

88 PRINCES STREET,
Edinburgh, October 1872.

EDMONSTON & DOUGLAS'

LIST OF WORKS

—000—

The Culture and Discipline of the Mind, and other Essays.

By JOHN ABERCROMBIE, M.D. New Edition. Fcap. 8vo, cloth, 3s. 6d.

Wanderings of a Naturalist in India,

The Western Himalayas, and Cashmere. By DR. A. L. ADAMS of the 22d Regiment. 8vo, with Illustrations, price 10s. 6d.

"The author need be under no apprehension of wearying his readers. . . . He prominently combines the sportsman with the naturalist."—*Sporting Review*.

Notes of a Naturalist in the Nile Valley and Malta.

By ANDREW LEITH ADAMS. Author of 'Wanderings of a Naturalist in India.' Crown 8vo, with Illustrations, price 15s.

"Most attractively instructive to the general reader."—*Bell's Messenger*.

Alexandra Feodorowna, late Empress of Russia.

By A. TH. VON GRIMM, translated by LADY WALLACE. 2 vols. 8vo, with Portraits, price 21s.

"Contains an amount of information concerning Russian affairs and Russian society."—*Morning Post*.

Always in the Way.

By the author of 'The Tommiebeg Shootings.' 12mo, price 1s. 6d.

The Malformations, Diseases, and Injuries of the Fingers

and Toes, and their Surgical Treatment. By THOMAS ANNANDALE, F.R.C.S. 8vo, with Illustrations, price 10s. 6d.

Odal Rights and Feudal Wrongs.

A Memorial for Orkney. By DAVID BALFOUR of Balfour and Trenaby. 8vo, price 6s.

Sermons by the late James Bannerman, D.D., Professor of

Apologetics and Pastoral Theology, New College, Edinburgh. In 1 vol., extra fcap. 8vo, price 5s.

The Life, Character, and Writings of Benjamin B
F.R.C.S.E., F.R.S.E., author of a 'System of Surgery,' and other Works.
his Grandson, BENJAMIN BELL, F.R.C.S.E. Fcap. 8vo, price 3s. 6d.

The Holy Grail. An Inquiry into the Origin and Sign
cation of the Romances of the San Greäl. By Dr. F. G. BERGMANN. F
8vo, price 1s. 6d.

"Contains, in a short space, a carefully-expressed account of the romance
chivalry, which compose what has been called the Epic cycle of the San Greäl
Athenæum.

Homer and the Iliad.

In Three Parts. By JOHN STUART BLACKIE, Professor of Greek in the U
versity of Edinburgh. 4 vols. demy 8vo, price 42s.

By the same Author.

Four Phases of Morals: Socrates, Aristotle, Christiani
and Utilitarianism. Lectures delivered before the Royal Institution, Lon
Fcap. 8vo, price 6s.

On Democracy.

Sixth Edition, price 1s.

Musa Burschicosa.

A Book of Songs for Students and University Men. Fcap. 8vo, price 2s. 6d.

War Songs of the Germans, translated, with the Music, &

Historical Illustrations of the Liberation War and the Rhine Boundary Ques
Fcap. 8vo, price 2s. 6d. cloth, 2s. paper. *Dedicated to Thomas Carlyle.*

On Greek Pronunciation.

Demy 8vo, 3s. 6d.

Political Tracts.

No. 1. GOVERNMENT. No. 2. EDUCATION. Price 1s. each.

On Beauty.

Crown 8vo, cloth, 8s. 6d.

Lyrical Poems.

Crown 8vo, cloth, 7s. 6d.

The New Picture Book. Recreative Instruction.

Pictorial Lessons on Form, Comparison, and Number, for Children under 8
Years of Age. With Explanations by NICHOLAS BOHNY. Fifth Edition.
36 oblong folio coloured Illustrations. Price 7s. 6d.

The Home Life of Sir David Brewster.

By his daughter, Mrs. GORDON. 2d Edition. Crown 8vo, price 6s.

"With his own countrymen it is sure of a welcome, and to the *savans*
Europe, and of the New World, it will have a real and special interest of its own."
—*Pall Mall Gazette*.

France under Richelieu and Colbert.

By J. H. BRIDGES, M.B. Small 8vo, price 8s. 6d.

Works by John Brown, M.D., F.R.S.E.

LOCKE AND SYDENHAM. Extra fcap. 8vo, price 7s. 6d.

HORÆ SUBSECIVÆ. Seventh Edition. Extra fcap. 8vo, price 7s. 6d.

LETTER TO THE REV. JOHN CAIRNS, D.D. Second Edition, crown 8vo, sewed, 2s.

ARTHUR H. HALLAM; Extracted from 'Horæ Subsecivæ.' Fcap. sewed, 2s.; cloth, 2s. 6d.

RAB AND HIS FRIENDS; Extracted from 'Horæ Subsecivæ.' Forty-sixth thousand. Fcap. sewed, 6d.

RAB AND HIS FRIENDS. Cheap Illustrated Edition. Square 18mo; ornamental wrapper. *[In October.]*

RAB AND HIS FRIENDS. With Illustrations by Sir George Harvey, R.S.A., Sir J. Noel Paton, R.S.A., and J. B. New Edition, small quarto, cloth, price 3s. 6d.

MARJORIE FLEMING: A Sketch. Fifteenth thousand. Fcap. sewed, 6d.

OUR DOGS; Extracted from 'Horæ Subsecivæ.' Nineteenth thousand. Fcap. sewed, 6d.

"WITH BRAINS, SIR;" Extracted from 'Horæ Subsecivæ.' Fcap. sewed, 6d.

MINCHMOOR. Fcap. sewed, 6d.

JEEMS THE DOORKEEPER: A Lay Sermon. Price 6d.

THE ENTERKIN. Price 6d.

Memoirs of John Brown, D.D.

By the REV. J. CAIRNS, D.D., Berwick, with Supplementary Chapter by his Son JOHN BROWN, M.D. Fcap. 8vo, cloth, 9s. 6d.

Select Hymns for Church and Home.

By R. BROWN-BORTHWICK. 18mo, price 2s. 6d.

The Finger of God in the Disruption and the Christian

Ministry, being the Opening and Closing Addresses delivered at the General Assembly of the Free Church of Scotland, May 1872, by CHARLES J. BROWN, D.D., Moderator. 8vo, price 1s.

The Biography of Samson

Illustrated and Applied. By the REV. JOHN BRUCE, D.D., Minister of Free St. Andrew's Church, Edinburgh. Second Edition. 18mo, cloth, 2s.

The Life of Gideon.

By Rev. JOHN BRUCE, D.D., Free St. Andrew's Church, Edinburgh. 1 vol. fcap. 8vo, price 5s.

"We commend this able and admirable volume to the cordial acceptance of our readers."—*Daily Review.*

Tragic Dramas from History.

By ROBERT BUCHANAN, M.A., late Professor of Logic and Rhetoric in the University of Glasgow. 2 vols. fcap. 8vo, price 12s.

By the Loch and River Side.

Forty Graphic Illustrations by a New Hand. Oblong folio, handsomely bound, 21s.

The De Oratore of Cicero.

Translated by F. B. CALVERT, M.A. Crown 8vo, price 7s. 6d.

My Indian Journal,

Containing descriptions of the principal Field Sports of India, with Notes on Natural History and Habits of the Wild Animals of the Country. By WALTER CAMPBELL, author of 'The Old Forest Ranger.' 8vo, with illustrations, price 16s.

Popular Tales of the West Highlands,

Orally Collected, with a translation by J. F. CAMPBELL. 4 vols. extra cloth, 32s.

Inaugural Address at Edinburgh,

April 2, 1866, by THOMAS CARLYLE, on being Installed as Rector of the University there. Price 1s.

Carswell's Gaelic Prayer Book.

The Prayer Book, commonly called John Knox's Liturgy. Translated into Gaelic, A.D. 1567, by Mr. JOHN CARSWELL, Bishop of the Isles. Edited, with an English Translation, by THOMAS M'LAUCHLAN, LL.D., Translator of the Gaelic of the Dean of Lismore. 4to, half Roxburgh. [In O

On the Constitution of Papal Conclaves.

By W. C. CARTWRIGHT, M.P. Fcap. 8vo, price 6s. 6d.

"A book which will, we believe, charm careful students of history, and will dissipate much of the ignorance which in this country surrounds the subject.—*Spectator*."

Gustave Bergenroth. A Memorial Sketch.

By W. C. CARTWRIGHT, M.P. Author of 'The Constitution of Papal Conclaves.' Crown 8vo, price 7s. 6d.

"To those who knew this accomplished student, Mr. Cartwright's eulogistic memoir will be very welcome."—*Standard*.

Life and Works of Rev. Thomas Chalmers, D.D., LL.D.

MEMOIRS OF THE REV. THOMAS CHALMERS. By REV. W. HANNA, D.D., LL.D. 2 vols., 8vo, cloth, £2 : 2s.

— Cheap Edition, 2 vols., crown 8vo, cloth, 12s.

POSTHUMOUS WORKS, 9 vols., 8vo—

Daily Scripture Readings, 3 vols., £1 : 11 : 6. Sabbath Scripture Readings, 3 vols., £1 : 1s. Sermons, 1 vol., 10s. 6d. Institutes of Theology, 1 vol., £1 : 1s. Prelections on Butler's Analogy, etc., 1 vol., 10s. 6d.

Sabbath Scripture Readings. Cheap Edition, 2 vols., crown 8vo, 10s.

Daily Scripture Readings. Cheap Edition, 2 vols., crown 8vo, 10s.

ASTRONOMICAL DISCOURSES, 1s. COMMERCIAL DISCOURSES, 1s.

SELECT WORKS, in 12 vols., crown 8vo, cloth, per vol., 6s.

Lectures on the Romans, 2 vols. Sermons, 2 vols. Natural Theology, on Butler's Analogy, etc., 1 vol. Christian Evidences, Lectures on Evidences, etc., 1 vol. Institutes of Theology, 2 vols. Political Economy with Cognate Essays, 1 vol. Polity of a Nation, 1 vol. Church and State Establishments, 1 vol. Moral Philosophy, Introductory Essays, 1 vol.

Characteristics of Old Church Architecture, etc.,

In the Mainland and Western Islands of Scotland. 4to, with illustrations,

Dainty Dishes.

Receipts collected by LADY HARRIETT ST. CLAIR. New Edition, with many new Receipts. Crown 8vo. Price 5s.

"Well worth buying, especially by that class of persons who, though their incomes are small, enjoy out-of-the-way and recherché delicacies."—*Times*.

The Constitution Violated.

An Essay by the Author of 'The Memoir of John Grey of Dilston,' dedicated to the Working Men and Women of Great Britain. Crown 8vo, 3s. 6d.

Sir John Duke Coleridge.

Inaugural Address at Edinburgh Philosophical Institution, Session 1870-71. 8vo, price 1s.

Wild Men and Wild Beasts—Adventures in Camp and Jungle. By LIEUT.-COLONEL GORDON CUMMING. With Illustrations by Lieut.-Col. BAIGRIE and others. Second edition. Demy 4to, price 24s.

Also, a Cheaper Edition, with *Lithographic* Illustrations. 8vo, price 12s.

Notes on the Natural History of the Strait of Magellan

and West Coast of Patagonia, made during the voyage of H.M.S. 'Nassau' in the years 1866, 1867, 1868, and 1869. By ROBERT O. CUNNINGHAM, M.D., F.R.S., Naturalist to the Expedition. With Maps and numerous Illustrations. 8vo, price 15s.

"There is a good deal of interesting and novel information in the present volume, and we can recommend it especially to those whose tastes lie in that direction."—*Standard*.

The Annals of the University of Edinburgh.

By ANDREW DALZEL, formerly Professor of Greek in the University of Edinburgh; with a Memoir of the Compiler, and Portrait after Raeburn. 2 vols. demy 8vo, price 21s.

Gisli the Outlaw.

From the Icelandic. By G. W. DASENT, D.C.L. Small 4to, with Illustrations, price 7s. 6d.

The Story of Burnt Njal;

Or, Life in Iceland at the end of the Tenth Century. From the Icelandic of the Njals Saga. By GEORGE WEBBE DASENT, D.C.L. 2 vols. 8vo, with Map and Plans, price 28s.

Select Popular Tales from the Norse.

For the use of Young People. By G. W. DASENT, D.C.L. New Edition, with Illustrations. Crown 8vo, 6s.

Plates and Notes relating to some Special Features in Structures called Pyramids. By ST. JOHN VINCENT DAY, C.E., F.R.S.S.A. Royal folio, price 28s.**Papers on the Great Pyramid.**

By ST. JOHN VINCENT DAY, C.E., F.R.S.S.A. 8vo, price 4s.

The Law of Railways applicable to Scotland, with a
Appendix of Statutes and Forms. By FRANCIS DEAS, M.A., LL.B., Advocate.
1 vol. Royal 8vo. [In the press.]

On the Application of Sulphurous Acid Gas
to the Prevention, Limitation, and Cure of Contagious Diseases. By JAMES
DEWAR, M.D. Thirteenth edition, price 1s.

Rheumatism and Rheumatic Gout treated on Antiseptic
Principles. By JAMES DEWAR, M.D. Price 1s.

Dick and I.

Uniform with 'Little Tales for Tiny Tots,' with six Illustrations. Square 18mo
price 1s.

Memoir of Thomas Drummond, R.E., F.R.A.S., Under-Secretary
to the Lord-Lieutenant of Ireland, 1835 to 1840. By JOHN F. McLENNAN,
Advocate. 8vo, price 15s.

"A clear, compact, and well-written memoir of the best friend England ever
gave to Ireland."—*Examiner*.

Political Survey.

By MOUNTSTUART E. GRANT DUFF, Member for the Elgin District of Burghs.
Author of 'Studies in European Politics,' 'A Glance over Europe,' &c. &c. 8vo
price 7s. 6d.

"In following up his 'Studies in European Politics' by the 'Political Survey'
here before us, Mr. Grant Duff has given strong evidence of the wisdom of the
choice made by the Ministry in appointing him Under-Secretary for India. In the
space of about 240 pages, he gives us the cream of the latest information about
the internal politics of no less than forty-four different countries under four heads
according to their situation in Europe, Asia, and Africa, Northern and Central
America, or South America."—*Pall Mall Gazette*.

By the same Author.

Elgin Speeches. 8vo, cloth, price 8s. 6d.

A Glance over Europe. Price 1s.

Address as Rector at the University of Aberdeen. Price 1s.

East India Financial Statement, 1869. Price 1s.

Remarks on the Present Political Situation. Price 1s.

Veterinary Medicines; their Actions and Uses.

By FINLAY DUN. Third Edition, revised and enlarged. 8vo. [In the press.]

Social Life in Former Days;

Chiefly in the Province of Moray. Illustrated by letters and family papers. By
E. DUNBAR DUNBAR, late Captain 21st Fusiliers. 2 vols. demy 8vo, price
19s. 6d.

Deep-Sea Soundings.

COLLOQUIA PERIPATETICA. By the late JOHN DUNCAN, LL.D., Professor of Hebrew in the New College, Edinburgh; being Conversations in Philosophy, Theology, and Religion. Edited by Rev. W. KNIGHT. Third Edition. 1 vol. fcap. 8vo. Price 3s. 6d.

"Since these lectures were published there has appeared an exceedingly interesting volume, entitled 'Colloquia Peripatetica,' by the late John Duncan, LL.D., Professor of Hebrew in the New College, Edinburgh. These Colloquies are reported by the Rev. William Knight, who seems to be admirably adapted for the task he has undertaken. His friend must have been a man of rare originality, varied culture, great vigour in expressing thoughts, which were worthy to be expressed and remembered. . . . The reader who shall give himself the benefit and gratification of studying this short volume (it will suggest more to him than many of ten times its size) will find that I have not been bribed to speak well of it by any praise which Dr. Duncan has bestowed on me. The only excuse for alluding to it is, that it contains the severest censure on my writings which they have ever incurred, though they have not been so unfortunate as to escape censure. . . . Against any ordinary criticism, even a writer who is naturally thin-skinned becomes by degrees tolerably hardened. One proceeding from a man of such learning and worth as Dr. Duncan I have thought it a duty to notice." — *Extract from Preface to 'The Conscience.'* By the late Professor F. D. Maurice. Second Edition, 1872.

Memoir of the late John Duncan, LL.D., Professor of Hebrew,

New College, Edinburgh. By the Rev. DAVID BROWN, D.D. Second edition, crown 8vo, cloth. [In October.

"Dr Brown's book must be read and re-read. We must therefore refer our thoughtful and inquiring readers to this discriminating and carefully wrought biography."—*Literary World.*

Edmonston and Douglas' Juvenile Library.

Square 18mo, with Illustrations. 1s. each.

DICK AND I.

LITTLE TALES FOR TINY TOTS.

BIRDS' NEST STORIES.

THE CHARITY BAZAAR.

NELLY RIVERS' GREAT RICHES.

STORIES TOLD IN THE WOODS.

NEW NIGHT-CAPS.

* * * Other volumes of this attractive series in preparation.

Karl's Legacy.

By the Rev. J. W. EBSWORTH. 2 vols. ex. fcap. 8vo. Price 6s. 6d.

Charlie and Ernest; or, Play and Work.

A Story of Hazlehurst School, with Four Illustrations by J. D. By M. BETHAM EDWARDS. Royal 16mo, 8s. 6d.

A Memoir of the Right Honourable Hugh Elliot.

By his Granddaughter, the COUNTESS of MINTO. 8vo, price 12s.

"Lady Minto produced a valuable memoir when she printed the substance of the work before us for private circulation in 1862. It now, in its completed shape, presents a full-length and striking portrait of a remarkable member of a remarkable race."—*Quarterly Review.*

The Spiritual Order, and other Papers selected from the MSS.

of the late THOMAS ERSKINE of Linlathen. Crown 8vo, cloth, price 5s.

"It will for a few have a value which others will not the least understand. But all must recognise in it the utterance of a spirit profoundly penetrated with the sense of brotherhood, and with the claims of common humanity."—*Spectator.*

Scenes from the Life of Jesus.

By SAMUEL GREG. Second Edition, enlarged. Ex. fcap. 8vo, price 3s. 6d.

"One of the few theological works which can be heartily commended to all classes."—*Inverness Courier*.

Arboriculture; or, A Practical Treatise on Raising and

Managing Forest Trees, and on the Profitable Extension of the Woods and Forests of Great Britain. By JOHN GRIGOR, The Nurseries, Forres. 8vo, price 10s. 6d.

"He is a writer whose authorship has this weighty recommendation, that he can support his theories by facts, and can point to lands, worth less than a shilling an acre when he found them, now covered with ornamental plantations, and yielding through them a revenue equal to that of the finest corn-land in the country. . . . His book has interest both for the adept and the novice, for the large proprietor and him that has but a nook or corner to plant out."—*Saturday Review*.

"Mr. Grigor's practical information on all points on which an intending planter is interested is particularly good. . . . We have placed it on our shelves as a first-class book of reference on all points relating to Arboriculture; and we strongly recommend others to do the same."—*Farmer*.

An Ecclesiastical History of Scotland,

From the Introduction of Christianity to the Present Time. By GEORGE GRUB, A.M. 4 vols. 8vo, 42s.

Chronicle of Gudrun;

A Story of the North Sea. From the mediæval German. By EMMA LETHERBROW. With frontispiece by J. NOEL PATON, R.S.A. New Edition, price 5s.

Notes on the Early History of the Royal Scottish Academy.

By Sir GEORGE HARVEY, Kt., P.R.S.A. 8vo, price 3s. 6d.

The Resurrection of the Dead.

By WILLIAM HANNA, D.D., LL.D., author of "The Last Day of our Lord's Passion," etc. 1 vol. fcap. 8vo. [In October.

The Wars of the Huguenots.

By REV. WILLIAM HANNA, D.D., LL.D. Ex. fcap. 8vo, price 5s.

The Life of our Lord.

By the REV. WILLIAM HANNA, D.D., LL.D. 6 vols., handsomely bound in cloth extra, gilt edges, price 30s.

Separate vols., cloth, extra gilt edges, price 5s. each.

1. THE EARLIER YEARS OF OUR LORD. 8th Thousand.
2. THE MINISTRY IN GALILEE. Second Edition.
3. THE CLOSE OF THE MINISTRY. 6th Thousand.
4. THE PASSION WEEK. 5th Thousand.
5. THE LAST DAY OF OUR LORD'S PASSION. 47th Thousand.
6. THE FORTY DAYS AFTER THE RESURRECTION. 9th Thousand.

Heavenly Love and Earthly Echoes.

By a Glasgow Merchant. 3d Edition. 18mo, price 1s. 6d.

"We have read this volume with unmingled satisfaction. We very cordially recommend it, as one much fitted to commend religion to the young, to cheer and

help the tempted and desponding, and indeed to have a wholesome influence on the minds and hearts of all."—*Original Secession Magazine*.

"Fitted to be useful and heart-stirring to all who are in earnest in religion. We hope and believe it will reach many more editions."—*Christian Work*.

Herminius.

A Romance. By I. E. S. Fcap. 8vo, price 6s.

The Historians of Scotland.

An Annual Payment of £1 will entitle the Subscriber to Two volumes. *Price to Non-Subscribers, 15s. per volume.*

1. **Scotichronicon of John de Fordun, from a contemporary MS.** at the end of the Fourteenth century, preserved in the Library at Wolfenbüttel, in the Duchy of Brunswick; collated with other known MSS. of the original chronicle. Edited by Mr. WILLIAM F. SKENE. In 2 vols. demy 8vo. Vol. 1 ready for Subscribers. Vol. 2 completing the work in November.

In Preparation.

2. **The Metrical Chronicle of Andrew of Wyntoun, Prior of St. Serf's Inch in Lochleven, who died about 1426.** The work now printed entire for the first time, from the Royal MS. in the British Museum, collated with other MSS. Edited by Mr. DAVID LAING. In 3 vols. demy 8vo. Vols. 1 and 2 will be ready for subscribers in November.

If the Gospel Narratives are Mythical, what then?

Crown 8vo, price 3s. 6d.

"This is a striking little essay, . . . thoughtful and subtle. It is an attempt to show that something like the philosophy of the Christian Gospel would be forced upon us by the facts of our spiritual nature."—*Spectator*.

Lectures on Scotch Legal Antiquities.

By COSMO INNES, F.S.A., author of "Scotland in the Middle Ages."

Contents:—I. Introductory. II. Charters. III. Parliament. IV. The Old Church. V. Old Forms of Law. VI. Rural occupations. VII. Student's Guide Books. VIII. Appendix. In 1 vol. demy 8vo. *[In October.]*

Sketches of Early Scotch History.

By COSMO INNES, F.S.A., Professor of History in the University of Edinburgh.

1. The Church; its Old Organisation, Parochial and Monastic.
2. Universities.
3. Family History. 8vo, price 16s.

Concerning some Scotch Surnames.

By COSMO INNES, F.S.A., Professor of History in the University of Edinburgh. Small 4to, cloth antique, 5s.

Instructive Picture-Books.

Folio, 7s. 6d. each.

"These Volumes are among the most instructive Picture-books we have seen, and we know of none better calculated to excite and gratify the appetite of the young for the knowledge of nature."—*Times*.

I.

The Instructive Picture Book. A few Attractive Lessons from the Natural History of Animals. By ADAM WHITE, late Assistant, Zoological Department, British Museum. With 54 folio coloured Plates. Eighth Edition, containing many new Illustrations by Mrs. BLACKBURN, J. STEWART, GOURLAY STEELL, and others.

II.

The Instructive Picture Book. Lessons from the Vegetable World. By the Author of 'The Heir of Redclyffe,' 'The Herb of the Field,' etc. New Edition with 64 Plates.

III.

Instructive Picture Book. The Geographical Distribution of Animals, in Series of Pictures for the use of Schools and Families. By the late Dr. GREVILL. With descriptive letterpress. New Edition, with 60 Plates.

IV.

Pictures of Animal and Vegetable Life in all Lands. 48 Folio Plates.

V.

Recreative Instruction. Pictorial Lessons on Form, Comparison, and number for Children under 7 years of age, with explanations. By Nicholas Bohny. Fifth edition. 26 Oblong folio Plates, price 7s. 6d.

The History of Scottish Poetry,

From the Middle Ages to the Close of the Seventeenth Century. By the late DAVID IRVING, LL.D. Edited by JOHN AITKEN CARLYLE, M.D. With a Memoir and Glossary. Demy 8vo, 16s.

Sermons by the Rev. John Ker, D.D., Glasgow.

Ninth Edition. Crown 8vo, price 6s.

"This is a very remarkable volume of sermons. And it is no doubt a most favourable symptom of the healthiness of Christian thought among us, that we are so often able to begin a notice with these words.

"We cannot help wishing that such notice more frequently introduced to our readers a volume of Church of England sermons. Still, looking beyond our pale we rejoice notwithstanding.

"Mr. Ker has dug boldly and diligently into the vein which Robertson opened but the result, as compared with that of the first miner, is as the product of skilful machinery set against that of the vigorous unaided arm. There is no roughness, no sense of labour; all comes smoothly and regularly on the page—one thought evoked out of another. As Robertson strikes the rock with his tool, unlooked for sparkles tempt him on; the workman exults in his discovery; behind each beautiful, strange thought, there is yet another more strange and beautiful still. Whereas, in this work, every beautiful thought has its way prepared, and every strange thought loses its power of starting by the exquisite harmony of its setting. Robertson's is the glitter of the ore on the bank; Ker's is the uniform shining of the wrought metal. We have not seen a volume of sermons for many a day which will so thoroughly repay both purchase and perusal and re-perusal. And not the least merit of these sermons is, that they are eminently suggestive."—*Contemporary Review*.

"The sermons before us are indeed of no common order; among a host of competitors they occupy a high class—we were about to say the highest class—whether viewed in point of composition, or thought, or treatment.

“He has gone down in the diving-bell of a sound Christian philosophy, to the very depth of his theme, and has brought up treasures of the richest and most *recherché* character, practically showing the truth of his own remarks in the preface, ‘that there is no department of thought or action which cannot be touched by that gospel which is the manifold wisdom of God.’ These subjects he has exhibited in a style corresponding to their brilliancy and profoundness—terse and telling, elegant and captivating, yet totally unlike the tinsel ornaments laid upon the subject by an elaborate process of manipulation—a style which is the outcome of the sentiment and feelings within, shaping itself in appropriate drapery.”—*British and Foreign Evangelical Review*.

Studies for Sunday Evening; or, Readings in Holy Writ.

By LORD KINLOCH. New edition, in 2 vols. fcap. 8vo, price 9s.

Also separately.

Readings in Holy Writ, and Studies for Sunday Evening.

Price 4s. 6d. each.

Faith's Jewels.

Presented in Verse, with other devout Verses. By LORD KINLOCH. Ex. fcap. 8vo, price 5s.

The Circle of Christian Doctrine;

A Handbook of Faith, framed out of a Layman's experience. By LORD KINLOCH. Third and Cheaper Edition. Fcap. 8vo, 2s. 6d.

Time's Treasure;

Or, Devout Thoughts for every Day of the Year. Expressed in verse. By LORD KINLOCH. Fourth and Cheaper Edition. Fcap. 8vo, price 3s. 6d.

Devout Moments.

By LORD KINLOCH. Price 6d.

Supplemental Descriptive Catalogue of Ancient Scottish Seals.

By HENRY LAING. 4to, profusely illustrated, price £3 : 3s.

The Philosophy of Ethics:

An Analytical Essay. By SIMON S. LAURIE, A.M. Demy 8vo, price 6s.

Notes, Expository and Critical, on certain British Theories

of Morals. By SIMON S. LAURIE. 8vo, price 6s.

The Reform of the Church of Scotland

In Worship, Government, and Doctrine. By ROBERT LEE, D.D., late Professor of Biblical Criticism in the University of Edinburgh, and Minister of Greyfriars. Part I. Worship. Second Edition, fcap. 8vo, price 3s.

Life in Normandy;

Sketches of French Fishing, Farming, Cooking, Natural History, and Politics, drawn from Nature. By an ENGLISH RESIDENT. Third Edition, crown 8vo, cloth ex. gilt, price 4s. 6d.

A Memoir of Lady Anna Mackenzie,

Countess of Balcarres, and afterwards of Argyle, 1621-1706. By ALEXANDER LORD LINDSAY (Earl of Crawford). Fcap. 8vo, price 3s. 6d.

"All who love the byways of history should read this life of a loyal Covenant—*Atlas*.

Lismore, Book of the Dean of,

Specimens of Ancient Gaelic Poetry, collected between the years 1512 and 1712 by the Rev. JAMES M'GREGOR, Dean of Lismore—illustrative of the Language and Literature of the Scottish Highlands prior to the Sixteenth Century. Edited with a Translation and Notes, by the Rev. THOMAS MACLAUCHLAN. The Introduction and additional Notes by WILLIAM F. SKENE. 8vo, price 12s.

Literary Relics of the late A. S. Logan, Advocate, Sheriff of Forfarshire. Extra fcap. 8vo, price 8s. 6d.**Little Ella and the Fire-King,**

And other Fairy Tales. By M. W., with Illustrations by HENRY WARREN. Second Edition. 16mo, cloth, 3s. 6d. Cloth extra, gilt edges, 4s.

Little Tales for Tiny Tots.

With 6 Illustrations by WARWICK BROOKES. Square 16mo, price 1s.

A Survey of Political Economy.

By JAMES MACDONELL, M.A. Ex. fcap. 8vo, price 6s.

"The author has succeeded in producing a book which is almost as easy reading as a three-volume novel."—*Athenæum*.

"Of its class it is one of the best we have seen; and had we to choose for a beginner among the crowd of manuals and introductions to the study, there is much which would induce us to recommend the present volume."—*Spectator*.

"Mr Macdonell's book, entitled 'A Survey of Political Economy,' establishes him as a writer of authority on economical subjects."—MR. NEWMARCH.

Ten Years North of the Orange River.

A Story of Everyday Life and Work among the South African Tribes, from 1859 to 1869. By JOHN MACKENZIE, of the London Missionary Society. With Maps and Illustrations. 1 vol. crown 8vo, cloth, extra gilt, price 4s. 6d.

Nugæ Canoræ Medicæ.

By DOUGLAS MACLAGAN, Professor of Medical Jurisprudence in the University of Edinburgh. A new edition enlarged with Illustrations by THOMAS FAED, R.A.; WILLIAM DOUGLAS, R.S.A.; JAMES ARCHER, R.S.A.; JOHN BALLANTYNE, R.S.A. etc. In 1 vol. 4to.

[In November.

Select Writings: Political, Scientific, Topographical, and

Miscellaneous, of the late CHARLES MACLAREN, F.R.S.E., F.G.S., Editor of the *Scotsman*. Edited by ROBERT COX, F.S.A. Scot., and JAMES NICOL, F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen. With a Memoir and Portrait. 2 vols. crown 8vo, 15s.

Memorials of the Life and Ministry of Charles Calder

Mackintosh, D.D., of Tain and Dunoon. Edited, with a Sketch of the Religious History of the Northern Highlands of Scotland, by the Rev. WILLIAM TAYLOR, M.A. With Portrait. Second Edition, extra fcap. 8vo, price 4s. 6d.

Macvicar's (J. G., D.D.)

THE PHILOSOPHY OF THE BEAUTIFUL; price 6s. 6d. FIRST LINES OF SCIENCE SIMPLIFIED; price 5s. INQUIRY INTO HUMAN NATURE; price 7s. 6d.

Mary Stuart and the Casket Letters.

By J. F. N., with an Introduction by HENRY GLASSFORD BELL. Ex. fcap. 8vo, price 4s. 6d.

Max Havelaar;

Or, The Coffee Auctions of the Dutch Trading Company. By MULTATULI; translated from the original MS. by Baron Nahuys. With Maps, price 14s.

Why the Shoe Pinches.

A contribution to Applied Anatomy. By HERMANN MEYER, M.D., Professor of Anatomy in the University of Zurich. Price 6d.

The Estuary of the Forth and adjoining Districts viewed

Geologically. By DAVID MILNE HOME of Wedderburn. 8vo, cloth, with Map and Plans, price 5s.

The Herring :

Its Natural History and National Importance. By JOHN M. MITCHELL. With Six Illustrations, 8vo, price 12s.

The Insane in Private Dwellings.

By ARTHUR MITCHELL, A.M., M.D., Commissioner in Lunacy for Scotland etc. 8vo, price 4s. 6d.

Creeds and Churches.

By the Rev. SIR HENRY WELLWOOD MONCREIFF, Bart., D.D. Demy 8vo. Price 3s. 6d.

Ancient Pillar-Stones of Scotland :

Their Significance and Bearing on Ethnology. By GEORGE MOORE, M.D. 8vo, price 6s. 6d.

Heroes of Discovery.

By SAMUEL MOSSMAN. Crown 8vo, price 5s.

Political Sketches of the State of Europe—from 1814-1867.

Containing Ernest Count Münster's Despatches to the Prince Regent from the Congress of Vienna and of Paris. By GEORGE HERBERT, Count Münster. Demy 8vo, price 9s.

Biographical Annals of the Parish of Colinton.

By THOMAS MURRAY, LL.D. Crown 8vo, price 3s. 6d.

History Rescued, in Answer to "History Vindicated," being a recapitulation of "The Case for the Crown," and the Reviewers Reviewed, &c. the Wigtown Martyrs. By MARK NAPIER. 8vo, price 5s.

Nightcaps:

A Series of Juvenile Books. By "AUNT FANNY." 6 vols. square 16mo, cloth. In case, price 12s., or separately, 2s. each volume.

- | | | |
|----------------------|-------------------|---------------------|
| 1. Baby Nightcaps. | 3. Big Nightcaps. | 5. Old Nightcaps. |
| 2. Little Nightcaps. | 4. New Nightcaps. | 6. Fairy Nightcaps. |

"Neither a single story nor a batch of tales in a single volume, but a box of pretty little books of choice fiction, is Aunt Fanny's contribution to the new supply of literary toys for the next children's season. Imagine the delight of a little girl who, through the munificence of mamma or godmamma, finds herself possessor of Aunt Fanny's tastefully-decorated box. Conceive the exultation with which, raising the lid, she discovers that it contains six whole and separate volumes, and then say, you grown-up folk, whose pockets are bursting with florins, whether you do not think that a few of your pieces of white money would be well laid out in purchasing such pleasure for the tiny damsels of your acquaintance, who like to be sent to bed with the fancies of a pleasant story-teller clothing their sleep with nightcaps of dreamy contentment. The only objection we can make to the quality and fashion of Aunt Fanny's Nightcaps is, that some of their joyous notions are more calculated to keep infantile wearers awake all night than to dispose them to slumber. As nightcaps for the daytime, however, they are, one and all, excellent."—*Athenæum*.

NEW NIGHTCAPS. New cheaper Edition, Fancy Cover, price 1s.

ODDS AND ENDS—Price 6d. Each.

Vol. I., in Cloth, price 4s. 6d., containing Nos. 1-10.

Vol. II., Do. do. Nos. 11-19.

- | | | |
|---------------------------------------|-----------------------------------|----------------------|
| 1. Sketches of Highland Character. | 2. Convicts. | 3. Wayside Thoughts. |
| 4. The Enterkin. | 5. Wayside Thoughts—Part 2. | |
| 6. Penitentiaries and Reformatories. | 7. Notes from Paris. | |
| 8. Essays by an Old Man. | 9. Wayside Thoughts—Part 3. | |
| 10. The Influence of the Reformation. | 11. The Cattle Plague. | |
| 12. Rough Night's Quarters. | 13. On the Education of Children. | |
| 14. The Stormontfield Experiments. | 15. A Tract for the Times. | |
| 16. Spain in 1866. | 17. The Highland Shepherd. | |
| 18. Correlation of Forces. | 19. 'Bibliomania.' | |
| 20. A Tract on Twigs. | 21. Notes on Old Edinburgh. | |
| 22. Gold-Diggings in Sutherland. | 23. Post-Office Telegraphs. | |

The Bishop's Walk and The Bishop's Times.

By ORWELL. Fcap. 8vo, price 5s.

Man: Where, Whence, and Whither?

Being a glance at Man in his Natural-History Relations. By DAVID PAGE. LL.D. Fcap. 8vo, price 3s. 6d.

"Cautiously and temperately written."—*Spectator*.

The Great Sulphur Cure.

By ROBERT FAIRMAN, Surgeon. Thirteenth Edition, price 1s.

Kidnapping in the South Seas.

Being a Narrative of a Three Months' Cruise of H. M. Ship Rosario. By CAPTAIN GEORGE PALMER, R.N., F.R.G.S. 8vo, illustrated, 10s. 6d.

France: Two Lectures.

By M. PREVOST-PARADOL, of the French Academy. 8vo, price 2s. 6d.

"Should be carefully studied by every one who wishes to know anything about contemporary French History."—*Daily Review*.

Suggestions on Academical Organisation,

With Special Reference to Oxford. By MARK PATTISON, B.D., Rector of Lincoln College, Oxford. Crown 8vo, price 7s. 6d.

Practical Water-Farming.

By WM. PEARD, M.D., LL.D. 1 vol. fcap. 8vo, price 5s.

On Teaching Universities and Examining Boards.

By LYON PLAYFAIR, C.B., M.P. 8vo, price 1s.

On Primary and Technical Education.

By LYON PLAYFAIR, C.B., M.P. 8vo, price 1s.

Popular Genealogists;

Or, The Art of Pedigree-making. Crown 8vo, price 4s.

The Pyramid and the Bible:

The rectitude of the one in accordance with the truth of the other. By a CLERGYMAN. Ex. fcap. 8vo, price 3s. 6d.

Christ and his Seed: Central to all things; being a Series of

Expository Discourses in Paul's Epistle to the Ephesians. By JOHN PULSFORD, Author of 'Quiet Hours.' Square 8vo, price 8s. 6d.

A Critical History of the Christian Doctrine of Justification

and Reconciliation. By ALBRECHT RITSCHL, Professor Ordinarius of Theology in the University of Göttingen. Translated from the German, with the Author's sanction, by JOHN S. BLACK, M.A. 8vo, cloth, price 12s.

"An exceedingly valuable contribution to theological literature. The history begins no earlier than the Middle Ages; since he considers that in earlier times, while the theory of a price paid to Satan was current, there was no real theology on the subject. A more thorough historical study of the doctrine of the Atonement, and a correct understanding and appreciation of the various forms it has assumed in different schools, are very much needed in this country."—*British and Foreign Evangelical Review*.

Reminiscences of Scottish Life and Character.

By E. B. RAMSAY, M.A., LL.D., F.R.S.E., Dean of Edinburgh. Library Edition, in demy 8vo, with Portrait by James Faed, price 10s. 6d.

* * The original Edition in 2 vols., with Introductions, price 12s.; and the Popular Edition, price 2s., are still on sale.

"That venerable Dean, who is an absolute impersonation of the 'reminiscence' of all the Scottish Churches, who in his largeness of heart embraces them all and in his steadfast friendship, his generous championship of forgotten truths and of unpopular causes, proves himself to be in every sense the inheritor of the noble Scottish name which he so worthily bears."—*Dean Stanley's Lectures on the Church of Scotland.*

Dean Ramsay's Reminiscences.

Twenty-first Edition, in fcap. 8vo, boards, price 2s. ; cloth extra, 2s. 6d.

"The Dean of Edinburgh has here produced a book for railway reading of the very first class. The persons (and they are many) who can only under such circumstances devote ten minutes of attention to any page, without the certainty of dizzy or stupid headache, in every page of this volume will find some poignant anecdote or trait which will last them a good half-hour for after-laughter: one of the pleasantest of human sensations."—*Athenæum.*

Recess Studies.

Edited by SIR ALEXANDER GRANT, Bart., LL.D. 8vo, price 12s.

Rights of Labour, and the Nine Hours' Movement.

Addressed to the Men of Newcastle. By a LADY. Price One Penny.

Past and Present: or, Social and Religious Life in the North.

By H. G. REID. 1 vol., crown 8vo, illustrated, price 6s.

"These papers show great good sense, a thorough appreciation of the importance of social questions, and a deep conviction of the influence of principle and truth in a nation's true progress."—*Freeman.*

Art Rambles in Shetland.

By JOHN T. REID. Handsome 4to, cloth, profusely illustrated, price 25s.

"This record of Art Rambles may be classed among the most choice and highly finished of recent publications of this sort."—*Saturday Review.*

The One Church on Earth. How it is manifested, and what

are the Terms of Communion with it. By Rev. JOHN ROBERTSON, A. A. Arbroath. Extra fcap. 8vo, price 3s. 6d.

Historical Essays in connection with the Land and the

Church, etc. By E. WILLIAM ROBERTSON, Author of 'Scotland under the Early Kings.' In 1 vol. 8vo., price 10s. 6d.

CONTENTS.

STANDARDS OF THE PAST IN WEIGHT AND CURRENCY.

PART I.—1. The Roman and Byzantine Pounds. 2. Talents of the Classic Era. 3. The Roman Currency. 4. The Stipendium. 5. Early Byzantine Currency. Approximate Standards.

PART II.—1. Early Substitutes for a Coinage. 2. Currency of the Early Franks and the House of Capet. 3. Early Germanic and Frisian Currency. 4. Norwegian and Irish Currency. 5. Morabotin and Early Spanish Currency. 6. Early English Currency and Standards. Medieval Standards.

THE YEAR AND THE INDUCTION.

THE LAND.—1. The Acre. 2. The Hide. 3. The Land-gavel. 4. The Scottish. 5. Scottish Measurements. 6. Irish Measurements. 7. Irish Land-tenure. The Toshach and the Thane.

CHAPTERS OF ENGLISH HISTORY BEFORE THE CONQUEST.—1. The King's Wife. 2. Handfasting. 3. The King's Kin. 4. Dunstan and his Policy. 5. The Coronation of Edgar.

ROME.

In 1 vol. Demy 8vo, cloth, price 10s. 6d.

Scotland under her Early Kings.

A History of the Kingdom to the close of the 13th century. By E. WILLIAM ROBERTSON. In 2 vols. 8vo, cloth, 36s.

"Mr Robertson, in the Appendix to his "Scotland under her Early Kings" on the English claims, appears to the Editor to have completely disposed of the claims founded on the passages in the Monkish Historians prior to the Norman Conquest. This paper is one of the acutest and most satisfactory of these very able essays."—*W. F. Skene in Preface to 'Chronicles of the Picts and Scots.'*

Rosebery, Lord, on the Union of England and Scotland.
8vo, 6d.

Doctor Antonio.

A Tale. By JOHN RUFFINI. Cheap Edition, crown 8vo, boards, 2s. 6d.

Lorenzo Benoni ;

Or, Passages in the Life of an Italian. By JOHN RUFFINI. With Illustrations. Crown 8vo, cloth gilt, 5s. Cheap Edition, crown 8vo, boards, 2s. 6d.

The Salmon ;

Its History, Position, and Prospects. By ALEX. RUSSEL. 8vo, price 7s. 6d.

Druidism Exhumed. Proving that the Stone Circles of

Britain were Druidical Temples. By Rev. JAMES RUST. Cheap. 8vo, price 4s. 6d.

Gowodean :

A Pastoral, by JAMES SALMON. 8vo, price 6s.

Natural History and Sport in Moray.

Collected from the Journals and Letters of the late CHARLES ST. JOHN, Author of 'Wild Sports of the Highlands.' With a short Memoir of the Author. Crown 8vo, price 8s. 6d.

A Handbook of the History of Philosophy.

By DR. ALBERT SCHWEGLER. Fourth Edition. Translated and Annotated by J. HUTCHISON STIRLING, LL.D., Author of the 'Secret of Hegel.' Crown 8vo, price 6s.

"Schwegler's is the best possible handbook of the history of philosophy, and there could not possibly be a better translator of it than Dr. Stirling."—*Westminster Review*.

The Scottish Poor-Laws: Examination of their Policy, History, and Practical Action.

By SCOTUS. 8vo, price 7s. 6d.

"This book is a magazine of interesting facts and acute observations upon this vitally important subject."—*Scotsman*.

Gossip about Letters and Letter-Writers.

By GEORGE SETON, Advocate, M.A. Oxon., F.S.A. Scot. Cheap. 8vo, price 5s.

"A very agreeable little brochure which anybody may dip into with satisfaction to while away idle hours."—*Echo*.

'Cakes, Leeks, Puddings, and Potatoes.'

A Lecture on the Nationalities of the United Kingdom. By GEORGE SET
Advocate, M.A. Oxon., etc. Second Edition. Fcap. 8vo, sewed, price 6d.

Culture and Religion.

By J. C. SHAIRP, Principal of the United College of St. Salvator and
Leonards, St. Andrews. Third Edition, fcap. 8vo, price 3s. 6d.

"A wise book, and unlike a great many other wise books, has that careful
shaded thought and expression which fits Professor Shairp to speak for Culture
less than for Religion."—*Spectator*.

John Keble :

An Essay on the Author of the 'Christian Year.' By J. C. SHAIRP, Prin-
cipal of the United College of St. Salvator and St. Leonards, St. Andrews. Fcap.
price 3s.

Studies in Poetry and Philosophy.

By J. C. SHAIRP, Principal of the United College of St. Salvator and
Leonard's, St. Andrews. Second Edition, 1 vol. fcap. 8vo, price 6s.

The Shores of Fife; or, the Forth and Tay.

Comprising Inland Scenery in Fife, Perth, Clackmannan, Kinross, and Stirling
with frontispiece—"Queen Margaret expounding the Scriptures to Malcolm C-
more," presented by SIR NOEL PATON, Knight, R.S.A., Her Majesty's Linner
Scotland; and original drawings, by WALLER H. PATON, R.S.A., SAMUEL BOU-
A.R.S.A., JOHN LAWSON, W. F. VALLANCE, E. T. CRAWFORD, R.S.A., CLARK STANT-
A.R.S.A., J. H. OSWALD, JOHN T. REID, and other Artists. Engraved by WILL-
BALLINGALL.

CONTAINING—

AN OUTLINE OF THE ARCHEOLOGY OF FIFE, by A. LAING, F.S.A. Scot., N
burgh-on-Tay.

HISTORICAL AND DESCRIPTIVE ACCOUNT OF ST. ANDREWS, by the Very R
PRINCIPAL TULLOCH, D.D.

HISTORICAL AND DESCRIPTIVE NOTES ON FALKLAND PALACE, LOCHLEVEN, RU-
LING BRIDGE, PERTH, DUNDEE, NEWPORT, BROUGHTY-FERRY, BELL ROCK, etc., by
Rev. GEORGE GILFILLAN.

STIRLING, ALLOA, CLACKMANNAN TOWER, CASTLE CAMPBELL, DOLLAR, KIN-
DINE, etc., by the Rev. J. MITCHELL HARVEY, M.A.

THE SHORES FROM LEVEN TO TORRYBURN, INCLUDING DUNFERMLINE, etc.,
the Rev. JAMES S. MILL.

THE SHORES FROM LARGO TO ST. ANDREWS, by the Author of 'The Hotel Du R
St. Jean.'

THE EDEN, CUPAR, KENNOWAY, KETTLE, LESLIE, MARKINCH, THORNTON, LEUCH-
LADYBANK, etc., by JOHN T. REID, Author of 'Art Rambles in Shetland.'

AN OUTLINE OF THE GEOLOGY OF FIFE, by DAVID PAGE, LL.D., Professor
Geology, College of Science, Newcastle.

SKETCH OF THE MINERALOGY OF FIFE, by M. FORSTER HEDDLE, M.D., Profo
of Chemistry, University of St. Andrews.

AN OUTLINE OF THE BOTANY OF FIFE, by CHARLES HOWIE, Secretary of
Largo Field Naturalists' Society.

4to, Cloth, price 30s.

Memoirs of the Life of Sir James Y. Simpson, Bart., M.D.

By JOHN DUNS, D.D., Professor of Natural Science, New College, Edinburgh.
Demy, 8vo. [In preparation.]

Archæological Essays by the late Sir James Y. Simpson,

Bart., M.D., D.C.L., one of her Majesty's Physicians for Scotland, and Professor of Medicine and Midwifery in the University of Edinburgh. Edited by JOHN STUART, LL.D., Secretary of the Society of Antiquaries of Scotland, Author of 'The Sculptured Stones of Scotland,' etc. etc. 2 vols. sm. 4to, half Roxburgh.

[In October.]

On Archaic Sculpturings of Cups and Circles upon Stones

and Rocks in Scotland, England, etc. By Sir J. Y. SIMPSON, Bart., M.D., D.C.L., Vice-President of the Society of Antiquaries of Scotland, etc. etc. 1 vol. small 4to, with Illustrations, price 21s.

Proposal to Stamp out Small-pox and other Contagious

Diseases. By Sir J. Y. SIMPSON, Bart., M.D., D.C.L. Price 1s.

The Four Ancient Books of Wales,

Containing the Cymric Poems attributed to the Bards of the Sixth Century. By WILLIAM F. SKENE. With Maps and Facsimiles. 2 vols. 8vo, price 36s.

"Mr. Skene's book will, as a matter of course and necessity, find its place on the tables of all Celtic antiquarians and scholars."—*Archæologia Cambrensis*.

The Coronation Stone.

By WILLIAM F. SKENE. Small 4to. With Illustrations in Photography and Zincography. Price 6s.

See Lismore, Book of Dean of.**The Sermon on the Mount.**

By the REV. WALTER C. SMITH, Author of 'The Bishop's Walk, and other Poems, by Orwell,' and 'Hymns of Christ and Christian Life.' Crown 8vo, price 6s.

Disinfectants and Disinfection.

By DR. ROBERT ANGUS SMITH. 8vo, price 5s.

"By common consent Dr. Angus Smith has become the first authority in Europe on the subject of Disinfectants. To this subject he has devoted a large portion of his scientific life; and now, in a compact volume of only 138 pages, he has condensed the result of twenty years of patient study. To Sanitary officers, to municipal and parochial authorities, and, indeed, to all who are particularly concerned for the public health and life; and who is not? we sincerely commend Dr. Angus Smith's treatise."—*Chemical News*.

Life and Work at the Great Pyramid.

With a Discussion of the Facts Ascertained. By C. PIAZZI SMYTH, F.R.S.S.L. and E., Astronomer-Royal for Scotland. 3 vols. demy 8vo, price 56s.

An Equal-Surface Projection for Maps of the World, and

its Application to certain Anthropological Questions. By C. PIAZZI SMYTH, F.R.S.S.L. & E., Astronomer-Royal for Scotland. 8vo, price 3s.

Britain's Art Paradise; or, Notes on some Pictures in the

Royal Academy, 1871. By the EARL of SOUTHESK. 8vo, sewed, price 1s.

Sir Walter Scott as a Poet.

By GILBERT MALCOLM SPROAT. 8vo, cloth, price 2s. 6d.

Scottish Liturgies of the Reign of James VI., from MSS.

the British Museum and Advocates' Library. Edited, with an Introduction and Notes, by the Rev. GEO. W. SPROTT, B.A. Extra fcap. 8vo, cloth, price 4s.

"The title of this book will be enough to make many pass it by as of no denominational interest. It is, on the contrary, one of national importance, and ought to be carefully studied by all who, through any line of descent, connect themselves with early Scotch Protestantism."—*Courant*.

The Doctrine of Christ Developed by the Apostles: a Treatise

on the Offices of the Redeemer, and the Doxology of the Redeemer. By R. EDWARD STEANE, D.D. 8vo, Price 10s. 6d.

"I have now attentively, and with great pleasure, perused your volume, and desire to express my sincere thankfulness to God and to you for so timely a publication."—J. H. HINTON, M.A.

"We have read this volume with more than ordinary pleasure. In the midst of so much in modern theological literature that is objectionable or doubtful, it is refreshing to meet with a clear, manly, outspoken exposition of those great evangelical doctrines which are in danger of being less commonly believed among us than they were among our fathers. The style of the whole book is clear, free, and vigorous; it is characterised by a tone of sustained eloquence which reminds more of the style of Dr. Chalmers than anything we have read for a long time."—*Wesleyan Methodist Magazine*.

"The style is graceful and flowing, the spirit devout and tender, and the theology of the Puritan type."—*General Baptist Magazine*.

"Here there is no uncertain sound on the doctrine of substitution and expiatory sacrifice, nor on that which Luther called '*Articulus stantis vel cadens ecclesie*,' the great doctrine of justification by faith."—*Daily Review*.

"In our judgment, a more valuable contribution in a single volume to the exposition, defence, and illustration of evangelical truth has not been often made. Thoughtful educated Christian laymen, students, and young ministers, will read with equal pleasure and profit."—*The Literary World*.

"A handsome welcome book, full of the old Gospel, and rich in tenderness and feeling, the ripe fruit of an honoured and green old age. The work is conscientious and lovingly done, and the result is a treatise on the Prophetic, Priestly, and Kingly Offices of Our Lord such as will give to all readers much intelligent thought and a much holy and suggestive sentiment. The text gives proof of careful study and ample scholarship, and it is further enriched with notes taken from recent Biblical criticism."—*The Freeman*.

History Vindicated in the Case of the Wigtown Martyr

By the Rev. ARCHIBALD STEWART. Second Edition. 8vo, price 3s. 6d.

Dugald Stewart's Collected Works.

Edited by Sir WILLIAM HAMILTON, Bart. Vols. I. to X. 8vo, cloth, each 12s.

Vol. I.—Dissertation. Vols. II. III. and IV.—Elements of the Philosophy of the Human Mind. Vol. V.—Philosophical Essays. Vols. VI. and VII.—Philosophy of the Active and Moral Powers of Man. Vols. VIII. and IX.—Lectures on Political Economy. Vol. X.—Biographical Memoirs of Adam Smith, LL.D., William Robertson, D.D., and Thomas Reid, D.D.; to which is prefixed a Memoir of Dugald Stewart, with Selections from his Correspondence, by John Veitch, M.A. Supplementary Vol.—Translations of Passages in Foreign Languages contained in the Collected Works; with General Index.

Jerrold, Tennyson, Macaulay, and other Critical Essays.

By JAMES HUTCHISON STIRLING, LL.D., Author of 'The Secret of Hegel' 1 vol. fcap. 8vo, price 5s.

"The author of 'The Secret of Hegel' here gives us his opinions of the life and works of those three great representative Englishmen whose names appear on the title-page of the work before us. Dr. Stirling's opinions are entitled to be heard and carry great weight with them. He is a lucid and agreeable writer, a profound metaphysician, and by his able translations from the German has proved his grasp of mind and wide acquaintance with philosophical speculation."—*Examiner*.

Christ the Consoler;

Or, Scriptures, Hymns, and Prayers, for Times of Trouble and Sorrow. Selected and arranged by the Rev. ROBERT HERBERT STORY, Minister of Roseneath. Fcap. 8vo, price 3s. 6d.

Recollections of Professor John Duncan.

By the Rev. A. MOODY STUART. Uniform with 'Colloquia Peripatetica.' Fcap. 8vo, cloth. [In December.]

Outlines of Scottish Archæology.

By Rev. G. SUTHERLAND. 12mo, sewed, profusely Illustrated, price 1s.

Works by the late Professor Syme.

OBSERVATIONS IN CLINICAL SURGERY. Second Edition. 8vo, price 8s. 6d.

STRICTURE OF THE URETHRA, AND FISTULA IN PERINEO. 8vo, 4s. 6d.

TREATISE ON THE EXCISION OF DISEASED JOINTS. 8vo, 5s.

ON DISEASES OF THE RECTUM. 8vo, 4s. 6d.

EXCISION OF THE SCAPULA. 8vo, price 2s. 6d.

Taine's History of English Literature.

Translated from the French by HENRI VAN LAUN. Third edition. 2 Vols. demy 8vo, price 21s.

* * * Copies of Vol. ii., Second Edition, may still be had to complete sets.

"Taine's History of English Literature' shows a sounder appreciation of the spirit of our literature, and is a better exponent of its growth from stage to stage, and of the minute characteristics of each stage, than any of the numerous summaries and outline histories that have been produced by Englishmen . . . of the general method pursued by M. Taine in this work we cannot speak too highly. . . . We are bound to bear testimony at once to the very great ability with which M. Van Laun has translated the work."—*The Examiner*.

"Taine's short chapter on Chaucer is thoroughly well worth reading. . . . His chapter on our dramatic literature is particularly noteworthy. . . . A better exposition of the nature and ramifications of Shakspeare's genius could hardly be looked for within the limits of a moderately short chapter."—*The Examiner*.

"M. van Laun has done a difficult task admirably well, by translating into the English of a scholar one of the most brilliant books that France has produced for years. . . . The analysis of a consummate critic and a brilliant rhetorician . . . with as true a sympathy as if all his life he had breathed the intellectual air of England."—*The Spectator*.

"It is the work of a brilliant and highly-cultivated intellect; of a consummate writer, who has sought impartially to lay before his countrymen the world of wealth which is treasured in our national literature, in all its beauty and its power."—*The Standard*.

"No other history of our literature can match M. Taine's in comprehensive grasp of thought, brilliancy of style, and trustworthiness of statement. It deserves a conspicuous place in every library. . . . Its appearance in an English dress will, we hope, largely increase the circle of readers and admirers."—*The Daily News*.

"The recommendation of some books to a man is a far better gift than the putting of a fifty pound-note in his pocket: and if any acute young student, well read in our ordinary English courses, finds Taine's book, he will truly find a treasure."—*The Overland Mail*.

"M. Taine reminds us, in his range of information, of Macaulay or Hallam. His 'History of English Literature' is a monument of patient skill and painstaking research, as much as of brilliant acumen and keenness of the critical faculty."—*The Birmingham Daily Mail*.

"It is unquestionably a most brilliant work . . . a book of unusual attractiveness. . . . M. van Laun has done his work with the conscientious carefulness of an accomplished scholar, and with the spirit and enthusiasm of a cultivated man of letters."—*The Edinburgh Evening Courant*.

"M. Taine is the most luminous and brilliant of French writers; he is almost as careful and as accurate as the most patient of German lexicographers. . . . F

is as brilliant as Macaulay, and almost as sympathetic as Carlyle. . . . Laun's translation is admirable. . . . We can commend the book to our readers as one of the most interesting, one of the best written, and one most honest and competent pieces of criticism in our language."—*The Glasgow Herald*.

Thermodynamics.

By P. G. TAIT, Professor of Natural Philosophy in the University of Edinburgh. 1 vol. 8vo, price 5s.

Day-Dreams of a Schoolmaster.

By D'ARCY W. THOMPSON. Second Edition. Fcap. 8vo, price 5s.

Sales Attici:

Or, The Maxims, Witty and Wise, of Athenian Tragic Drama. By D'ARCY WORTH THOMPSON, Professor of Greek in Queen's College, Galway. Fcap. 8vo, price 9s.

Two Little Rabbits, or the Sad Story of Whitetail.

By G. A. DALRYMPLE. With 8 Illustrations. Square 18mo, price 1s.

Hand-Book of the Education (Scotland) Act, 1872.

Containing—I. A digest of the Act, with subjects grouped for the convenience of School Boards. II. Copy of the Act, with Explanatory Notes. III. The repealed Acts, Industrial Schools' Act, etc., and Index. By JAMES TODD. Crown 8vo, price 2s. 6d.

Twelve Years in China:

By a British Resident. With coloured Illustrations. Second Edition. 8vo, cloth, price 10s. 6d.

Travels by Umbra. 8vo, price 10s. 6d.

Hotch-Pot.

By UMBRA. An Old Dish with New Materials. Fcap. 8vo, price 3s. 6d.

The Merchant's Sermon and other Stories.

By L. B. WALFORD. 18mo, price 1s. 6d.

"A volume of very modest appearance which deserves more than the notice for which we can find space. The four tales it contains are all pleasantly and spirited little stories. The last of these, 'Dolly Spanker's Green Feather,' is really admirable."—*Spectator*.

A History of the Battle of Bannockburn, fought A.D. 1314.

With Map and Armorial Bearings and Notices of the principal Warriors engaged in that Conflict. By ROBERT WHITE, Author of 'A History of the Battle of Otterburn.' 1 vol. 8vo, price 12s.

Dante's—The Inferno.

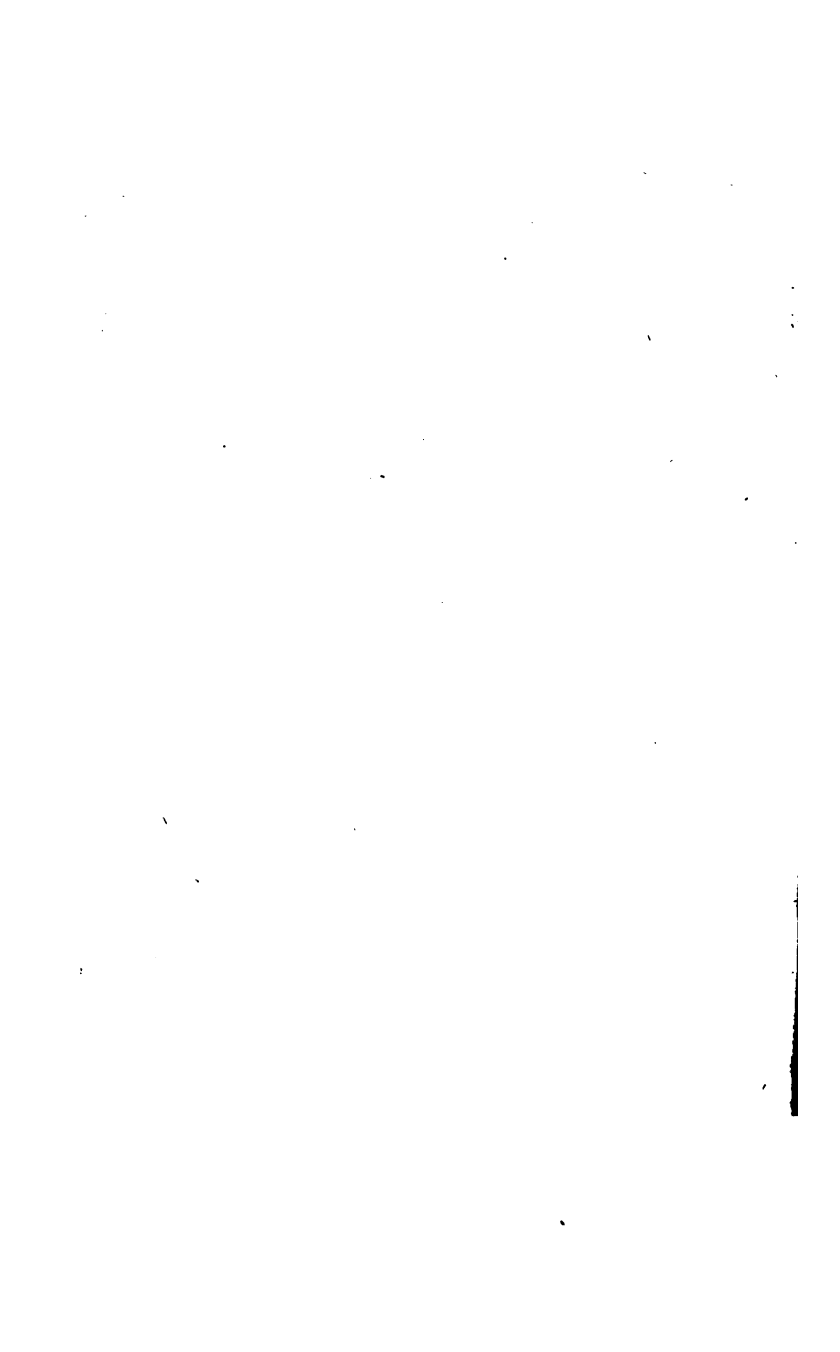
Translated line for line by W. P. WILKIE, Advocate. Fcap. 8vo, price 5s.

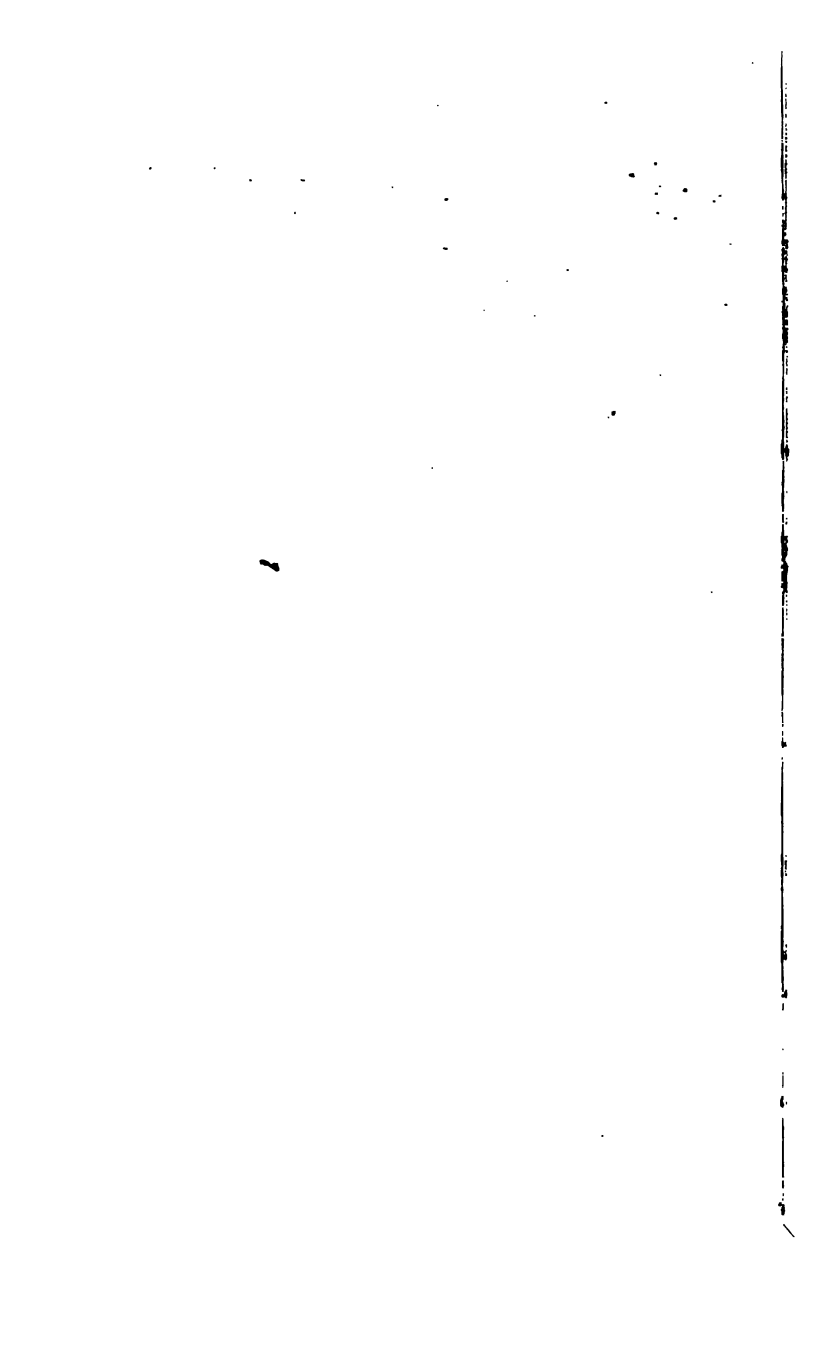
Researches on Colour-Blindness.

With a Supplement on the danger attending the present system of Railway and Marine Coloured Signals. By the late GEORGE WILSON, M.D. 8vo, 5s.

An Historical Sketch of the French Bar, from its Origin to the Present Day.

By ARCHIBALD YOUNG, Advocate. Demy 8vo. Price 10s. 6d. "A useful contribution to our knowledge of the leading French political and legal men of the present day."—*Saturday Review*.







THE NEW YORK PUBLIC LIBRARY
REFERENCE DEPARTMENT

**This book is under no circumstances to be
taken from the Building**

[illegible]



